

UNIVERSITY
OF TASMANIA

School of Land and Food

**Productive performance, rumen indices and meat
quality of concentrate–supplemented goats in Vietnam**

Quan Hai Nguyen

Submitted in fulfilment of the requirements for the Master of Agricultural Science degree

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Declaration

This is to certify that:

- The thesis contains no material which has been accepted for the award of other degree(s) or diploma(s) in any tertiary institution(s).
- To the best of my knowledge, the thesis contains no materials published or written by any other person(s), except where due reference is made in the text.

Q. H. Nguyen

University of Tasmania

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Supervisors

Dr. Aduli Malau-Aduli - Primary Supervisor

Dr. David Parsons - Co-Supervisor

Associate Prof. Peter Lane - Co-Supervisor

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Abstract

Twenty-five Vietnamese Bach Thao bucks were assessed at an average age of 7 months and body weight of 20.3 ± 0.8 kg. Goats were randomly allocated into five treatment groups of varying levels of concentrate supplementation: Control (*ad libitum* access to elephant grass), 0.6 %C (control plus 0.6% of concentrate), 1.2 %C (control plus 1.2% of concentrate), 1.8 %C (control plus 1.8% of concentrate), and 2.4 %C (control plus 2.4% of concentrate) as a percentage of liveweight on a dry matter basis. It was evident that increased concentrate levels had a positive effect on performance, productivity and meat quality of Vietnamese Bach Thao goats and the best response was reached at supplementation at the 1.8%C level. Specific outcomes included: 1) An increase in the level of dietary concentrate supplementation significantly increased feed intake, average daily gain (ADG), digestibilities of dry matter, organic matter and crude protein, and dressing percentage (DP). The highest ADG of 150 g/d and DP of 56% were observed in treatments 1.8 %C and 2.4 %C. 2) A significant increase in lean meat and a lower proportion of bone in the carcass was observed, but there was no difference in total fat percentage as the level of concentrate supplementation increased. 3) There was no difference in chemical composition or total saturated fatty acid composition of the *Longissimus dorsi* muscle, but the levels of monounsaturated fatty acids in the concentrate-supplemented groups were all significantly higher than in the control group. In conclusion, the tested hypothesis was accepted, and the key research question of the best concentrate supplementation level in Bach Thao goats was answered where treatment 1.8 %C produced the best growth, dressing percentage and meat quality responses. The study also indicated that Small Ruminant Nutrition System model can predict the DMI, ADG, nutrition digestibility and faecal characteristics of Vietnamese Bach Thao goats with satisfactory results for different ratios of forage and concentrate, when chemical compositions of the feeds are known.

Contents

Declaration.....	i
Acknowledgements.....	ii
Abstract.....	iii
Contents	iv
List of figures and tables.....	vii
List of abbreviations	ix
List of publications from thesis.....	x
Chapter 1: General Introduction	1
Chapter 2: Literature review	3
2.1. Genetic diversity and distribution of goats in Vietnam	3
2.2. Supplementary feed sources for goats	3
2.2.1 Tree Legume Leaves.....	3
2.2.2. Agro-industrial by-products.....	4
2.2.3. Concentrates.....	5
2.2.4. Nitrogen supplements	6
2.3 Rumen fermentation.....	7
2.4 Plasma metabolites.....	9
2.5 Meat quality	10
2.5.1 Carcass composition	10
2.5.1.1 Carcass weight and dressing percentage.....	10
2.5.1.2 Tissue Dissection.....	12
2.5.2 Meat Quality Characteristics.....	13
2.5.2.1 Meat pH	13

2.5.2.2 Meat colour	13
2.5.2.3 Meat chemical composition	14
2.5.3 Fatty acid profiles	15
2.6 Summary of identified knowledge gaps and research objectives	16
Chapter 3: Productive performance, rumen fermentation and plasma metabolites of concentrate-supplemented Bach Thao goats in Vietnam.....	28
3.1. Introduction.....	30
3.2. Materials and Methods.....	31
3.3. Results.....	35
3.4. Discussion.....	40
Conclusion	42
Chapter 4: Effect of concentrate supplementation on meat yield and quality indices of <i>Longissimus dorsi</i> muscle in Bach Thao goats	46
4.1. Introduction.....	47
4.2. Materials and Methods.....	49
4.3. Results.....	53
4.4. Discussion.....	59
Conclusion	61
Chapter 5: Small Ruminant Nutrition System Model: Comparative evaluation of prediction accuracy between observed and predicted data.....	64
5.1 Introduction.....	64
5.2 Materials and methods	65
5.3 Results.....	68
5.4 Discussion.....	75
Conclusions.....	76
Chapter 6: General summary and conclusion	78
6.1. Feed intake and average daily gain	78

6.2. Nutrient digestibility and rumen fluid characteristics	78
6.3. Meat quantity and quality	79
6.4. General conclusions	79
Appendix.....	80
Appendix 5.1 The initial weights of goats used as inputs in the model.....	80
Appendix 5.2 Dressing percentage ($M \pm S.D.$) of goats fed different levels of concentrates.....	80

List of figures and tables

Figures

Fig. 4.1 Fortnightly variation in body weight (kg) in goats..	53
Fig. 4.2 Change in pH of the <i>Longissimus dorsi</i> muscle after 24h post mortem of goats fed different levels of concentrate.....	56
Fig. 5.1 Relationship between observed and model-predicted dry matter intake (DMI) using the Small Ruminant Nutrition System.	69
Fig. 5.2 Relationship between observed and model-predicted average daily gain (ADG) using the Small Ruminant Nutrition System.	69
Fig. 5.3 Relationship between observed and model-predicted dry matter intake (DMI) for the digestibility period, using the Small Ruminant Nutrition System.	70
Fig. 5.4 Relationship between observed and model-predicted digestibility of dry matter (DDM) using the Small Ruminant Nutrition System.	71
Fig. 5.5 Relationship between observed and model-predicted digestibility of organic matter (DOM) using the Small Ruminant Nutrition System.	72
Fig. 5.6 Relationship between observed and model-predicted digestibility of crude protein (DCP) using the Small Ruminant Nutrition System.	72
Fig. 5.7 Relationship between observed and model-predicted dry matter faecal output using the Small Ruminant Nutrition System.	73
Fig. 5.8 Relationship between observed and model-predicted crude protein faecal output using the Small Ruminant Nutrition System.	74
Fig. 5.9 Relationship between observed and model-predicted crude protein faecal output using the Small Ruminant Nutrition System.	74

Tables

Table 3.1 The proportions of ingredients (g/kg DM) and nutrient contents of the concentrates and elephant grass.	32
Table 3.2 Feed intake (g) and average daily gain (g/day) of goats fed varying levels of concentrate (Least Squares Means \pm SD).	35
Table 3.3 Apparent nutrient digestibility of goats fed varying levels of concentrates (Least Square Means \pm S.D.)..	36
Table 3.4 Ammonia concentration and pH value of rumen fluid before and after 4 hours of feeding.....	37
Table 3.5 VFA profile (%) of rumen fluid before and 4 hours after feeding.....	38
Table 3.6 Plasma metabolites before and after the experimental period.	39
Table 4.1 The proportions of ingredients (g/kg DM) and nutrient contents of the mixed concentrate and elephant grass.....	50
Table 4.2 Dressing and meat-bone-fat percentages of Bach Thao goat fed varying levels of concentrate (Least Square Means).	54
Table 4.3 Colour and pH indices of <i>Longissimus dorsi</i> muscle of Bach Thao goats.....	55
Table 4.4 Chemical composition of the <i>Longissimus dorsi</i> muscle of Bach Thao goats (%).	56
Table 4.5 Fatty acid composition of the <i>Longissimus dorsi</i> muscle of Bach Thao goats (%).	58
Table 5.1 Summary of experimental details used to parameterize the SRNS model.....	65
Table 5.2 Feed quality values used to parameterize the small ruminant nutrition system model.	66
Table 5.3 Input variables used to evaluate the small ruminant nutrition system (SRNS) model.	67
Table 5.4 Coefficient of determination (r^2), root mean square error (RMSE), slope (b), and y-intercept (a) for regressions of observed and model-predicted outputs.....	68

List of abbreviations

AFRC, Agricultural and Food Research Council

AOAC, Association of Official Analytical Chemist International

CNCPS, Cornell Net Carbohydrate and Protein System

CP, Crude Protein

CSIRO, Commonwealth Scientific and Industrial Research Organisation

DCP, Digestibility of crude protein

DDM, Digestibility of dry matter

DOM, Digestibility of organic matter

DM, Dry matter

DMI, Dry matter intake

EE, Ether extract

FA, Fatty acids

MUFA, Monounsaturated fatty acids

NDF, Neutral detergent fibre

LWG, Liveweight gain

PUFA, Polyunsaturated fatty acids

SD, Standard deviation

SFA, Saturated fatty acids

SRNS, Small Ruminants Nutrition System

TIA, Tasmania Institute of Agriculture

VFA, Volatile fatty acids

List of journal manuscripts submitted for publication from thesis

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Chapter 1: General Introduction

The goat was the first domesticated animal by human beings for the purpose of generating livestock products. In the developing regions of the world especially, goats play a crucial role in food and economic security (Sahlu & Goetsch, 2005). High quality feeds are limited in tropical regions characterised by hot environments. Therefore, production systems based on natural grass or rangelands may lead to poor animal performance (Alexandre & Mandonnet, 2005). Thus, supplementation may be necessary to meet the goat's nutritional requirements and to avoid under feeding.

Vietnam is a sub-tropical country where goats are mainly located in environmentally harsh mountainous areas with small herd sizes ranging between 5 and 7 head (Mui, 2006). As a country with agriculture as a major livelihood option, there are many available feed resources such as rice bran, cassava powder, maize, etc, which can be used to formulate mixed concentrate supplements for goats. Therefore, their effective utilisation is especially important as it is likely to impact on animal performance, productivity and meat quality. Moreover, the demand for goat meat is increasing in many parts of the world, hence the confinement husbandry system with high quality feed has become more common (Goetsch *et al.*, 2011).

Theoretically, supplementation of goats with concentrates in the ration aims to increase energy density, protein intake, feed efficiency and balance between starch and forage. There are several research investigations on the use of concentrates and their levels of supplementation in goat diets (Cerrillo *et al.*, 1999; Haddad, 2005; Mushi *et al.*, 2009; Ryan *et al.*, 2007; Safari *et al.*, 2009; Urge *et al.*, 2004). These findings reported diverse and inconsistent effects on animal performance, meat yield and quality, probably due to differences in goat breed and type of concentrates utilised. Therefore, it is necessary to assess the impact of dietary supplementation with concentrates on goat production systems specific to Vietnam.

Based on a comprehensive investigation of current published literature, a number of questions relating to concentrate supplementation of Vietnamese Bach Thao goats remains unanswered:

1. How will concentrate supplementation affect productive performance, nutrient digestibility, meat yield and quality in Bach Thao goats?
2. What is the best level of concentrate supplementation for improving productivity?

To answer these research questions, this study tested the hypothesis that: Increased levels of concentrate supplementation will result in greater productivity and better meat quality in Bach Thao goats without any adverse impact on rumen fermentation indices and digestibility.

Therefore, the objectives of this thesis were:

1. To assess the effect of varying levels of concentrate supplementation on growth performance, digestibility, rumen fermentation and plasma metabolites of Bach Thao goats (Chapter 3).
2. To investigate the effect of concentrate supplementation levels on growth, liveweight, dressing percentage and meat quality attributes of Vietnamese Bach Thao goats (Chapter 4).
3. To evaluate the accuracy of prediction of the SRNS (Small Ruminant Nutrition System) model in a comparative analysis of model-predicted outputs and observed experimental data (Chapter 5).

Chapter 2: Literature review

2.1. Genetic diversity and distribution of goats in Vietnam

The main purpose of raising goats in Vietnam is to produce meat. There are only two breeds of local goats that account for nearly 95% of the total goat population. The most common breed of goat is the Co. It has a mature weight of about 20-30kg and is raised in all areas of Vietnam because it is well adapted to the prevailing climatic conditions. The second breed is known as Bach Thao, a crossbred between Co and introduced breeds which were brought into Vietnam by the French and are more commonly found in Ninh Thuan and Southern Vietnam (Nguyen *et al.*, 1996). The body weight of a mature Bach Thao goat is about 35-45 kg. According to the Food and Agriculture Organisation statistics (FAO, 2009), there were 1,375,100 sheep and goats in Vietnam. Besides the afore-mentioned, there are numerous exotic breeds that have been introduced to Vietnam such as the Boer, Jumnapari, Beetal, Anglo-Nubian, Saanen, Alpine, etc.; however, these breeds are less popular in Vietnam due to different management requirements with associated higher cost.

2.2. Supplementary feed sources for goats

2.2.1 Tree Legume Leaves

Goats have been acclaimed to be the most capable of consuming and efficiently utilising several multi-purpose plant leaves. In tropical areas, tree legumes have been used as supplementary feeds for grazing goats (Morand-Fehr, 2005) and such foliages are high in mineral content and as digestible as tropical grass (Leng *et al.*, 1992). The most common leaves which have been studied are *Leuceana leucocephala*, *Gliricidia sepium* and less frequently, cassava (*Manihot esculenta* Crantz), Jackfruit (*Antocarpus heterophyllus*), Flemingia (*Flemingia marcophylla*), etc. Most of the research studies on such forage tree species have focused on nutritive evaluation and substitution rates of proteins or concentrates in the diet.

The nutritive value and chemical composition of tree legumes are variable due to varietal differences (Azim *et al.*, 2001; Elseed *et al.*, 2002). However, these feeds have been reported as excellent protein sources and can be used as mixtures of leaf meal to replace soybean or peanut cake in conventional protein diets (Anbarasu *et al.*, 2002; Patra *et al.*, 2002). *Leuceana leucocephala* has a high protein content of around 30% CP and can be supplied in fresh form constituting 30-40% of the total diet (Dutta *et al.*, 1999; Eroarome, 2002). Similarly, supplementing the basal diet of guinea grass with 30% *Gliricidia sepium* was found to give the best performance in goats (Phimphachanhvongsod & Ledin, 2002) and it can be used to replace 30% of the concentrates (Hao & Ledin, 2001). In addition, Mui *et al.* (2001) observed that Jackfruit and Flemingia could be used as fresh and substituted protein sources in concentrates up to 100% and 25%, respectively. Although most tree legumes are reported to have high CP content, anti-nutritional factors like tannin, are considered detrimental to growth and productive performance (Norton, 1998). However, tannin can improve escape protein if the amount is not too much. In order to deal with these limitations, polyethylene glycol has been added to diets which elicited a better performance (Mui *et al.*, 2002). In general, the role of tannins in tree legumes has not been consistent (Norton, 1998). It could be concluded that tree legume forages play a crucial role in goat production as well as in other ruminants; however, it is necessary to have a complete understanding of the most efficient way to utilise them in typical livestock production systems so that they are considered by farmers as an attractive source of forage for use in feeding systems (Morand-Fehr, 2005).

2.2.2. Agro-industrial by-products

Agro-industrial by-products have been used as cheaper alternative feeds for goats. Generally, these by-products come from local crops and manufacturing industries, therefore, the nutritional content and utilization of such feeds differ among areas and regions. In Samoa and other Pacific countries, Areghoreet *et al.*, (2003) demonstrated that dry brewers' grain, cocoa shell, cocoa dust and desiccated coconut waste meal could be used in goat rations without reducing performance. Similarly, in South-East Asia, supplementing cassava hay at 25% of dietary DM resulted in optimum dry matter intake and reduced feed cost (Dunget *et al.*, 2005; Phengvichith & Ledin, 2007). Chanjula *et al.* (2007) reported that cassava chips could substitute 25% to 75% of corn in

the diet without adverse effect on performance of goats. Sunflower meal has been reported to completely substitute conventional protein sources like soybean without any difference in productive performance of goats in Jordan (Titi, 2003). Other studies to improve the nutritional value of agricultural by-products have utilised urea-treated rice straw and formaldehyde-treated soybeans. Titi (2003) found that fibrolytic enzyme treated sunflower meal was better than sunflower meal without treatment in improving the productive performance of goats. In conclusion, agro-industrial by-products are potentially good dietary sources for goat feeding and their utilisation depends on availability and production in each region.

2.2.3. Concentrates

In order to meet the nutrient requirements of goats under intensive production systems, the feeding regimes are increasingly containing high levels of concentrates (Zhao *et al.*, 2007). The role of concentrates in goat rations is intended to increase energy, protein, feed efficiency and balance between starch and forage.

The ratio of concentrate to forage in a ration impacts feed intake significantly. High concentrate levels in the diet increase dry matter intake (Haddad, 2005; Salim *et al.*, 2002; Tufarelliet *al.*, 2009), weight gain and with better feed efficiency, carcass characteristics at reduced feed costs (Haddad, 2005). The digestibilities of DM, OM and CP were reported to increase when the level of concentrates in the diets increased (Haddad, 2005; Cantalapiedra-Hijaret *al.*, 2009). Conversely, the digestibility of NDF and ADF decreased (Haddad, 2005).

Prieto *et al.* (2000) and Haddad (2005) suggested that dietary concentrates supplied up to 70% and CP of which at least 14% can meet the nutritional requirements of growing goats. Goetsch *et al.* (2003) concluded that dietary supplementation of goats comprising 75% concentrates increased feed intake because of better utilization of ME. Soto-Navarro *et al.* (2004) reported that when goats were fed dietary concentrates of up to 70% and CP of which at least 13% were not detrimentally affected by the source of protein. In general, the goat has a greater ability for utilisation of concentrates in the diet for improving feed efficiency than other small ruminants.

2.2.4. Nitrogen supplements

Protein plays an important role in the development and growth of ruminants, therefore, supplementing with adequate amounts of protein to meet nutritional requirements is crucial due to the high price of such supplementary feeding (CSIRO, 2007). Although the rumen can supply some essential amino acids to the host animal through microbial protein, it is not sufficient when the requirement of the animal for growth is high (Soto-Navarro *et al.*, 2006).

The quantity and quality of feeding protein is assessed by the amount of digestible protein leaving the stomach (DPLS). It is influenced by both microbial protein and rumen undegradable protein (RUP)(CSIRO, 2007). Crude protein from animal feeds is divided into rumen degradable protein (RDP) and RUP. Protein supplements for ruminants which keep the balance between RDP and RUP is the most efficient (Schwab *et al.*, 2005). There have been studies comparing different sources of supplementary protein (both RDP and RUP) for ruminants consuming low quality forages (Salisbury *et al.*, 2004). However, research on the optimal ratio between RDP: RUP have not been extensively defined in goats compared to sheep and cattle.

There have been some studies on dairy goats which concluded that there were no significant differences in milk production and composition when varying ratios of RDP: RUP were supplied (Laudadio & Tufarelli, 2010; Mishra & Rai, 1996). Salisbury *et al.*, (2004) found that if the degradable protein intake is sufficient in lambs, the rumen undegradable protein did not affect animal performance.

Research has also been conducted to compare the effect of different protein sources on goat performance. Grégoire *et al.*, (1996) observed that varying protein resources had little impact on growth rate and mohair growth. However, Litherland *et al.*, (2000) reported conflicting results when comparing the effect of four different protein sources, namely corn gluten meal, cottonseed meal, hydrolysed feather meal and menhaden fish meal on goat performance. Their results showed that ADG was greatest in goats supplemented with fish meal and mohair rate was highest in goats fed cottonseed meal, however, the reasons for these observations were not

explained clearly. The impact of protein supplements on ruminant performance depends on the content of protein in the forage. When the diet contains 70% concentrates and 13-14% CP, growth rate is not impacted by source of protein (Prieto *et al.*, 2000; Soto-Navarro *et al.*, 2004). This is due to the large population of microbes which use degradable protein to synthesise microbial protein for themselves before it flows to the small intestines as protein supply for the host animal. In general, protein supplementation is used most effectively with low quality forages as basal diets. The ratio of RDP: RUP should be balanced to have maximum of feed efficiency.

Another crucial factor is the level of crude protein in the diet. It has been well documented that an increase in the level of dietary protein supplement leads to an increase in dry matter intake and animal performance (Lu & Potchoiba, 2000; Shahjalal *et al.*, 2000; Tegene *et al.*, 2001). However, it is necessary to calculate precisely the amount of protein that is optimal for animal digestion and feed efficiency and is economically feasible to supplement. There have been many studies on optimal levels of protein in concentrate diets. The results from such investigations suggested different optimal levels of protein in the diet ranging from 14% (Prieto *et al.*, 2000), 16% (Titi *et al.*, 2000) to 20.3% (Shahjalal *et al.*, 2000). The concept of optimal dietary protein level depends on the output indices (Tegene *et al.*, 2001). Therefore, it is difficult to give a single suggested level. In addition, the percentage of CP in the diet depends on the proportion of concentrate, for example, 70% concentrate in the diet and 13% CP could meet the requirement of growing goats (Soto-Navarro *et al.*, 2004). The use of TMR (Total Mixed Ration) has been studied and Hwangbo *et al.*, (2009) suggested that CP in TMR of up to 18% was optimal for growth and development of black goats in Korea.

2.3 Rumen fermentation

Short chain fatty acids (SCFA)

The SCFA comprise mainly acetate, propionate and butyrate, and other small amounts of longer, straight and branched-chain fatty acids. They are known as end-products of microbial

fermentation. During the fermentation period, energy is generated in the form of ATP (adenosine tri phosphate) and used by microbes. The proportion of individual fatty acids depends on the nature of the diet. It is well recognized that a basal roughage diet results in high levels of acetate. In contrast, a high concentrate diet results in increased proportions of propionate. Bergman (1990) reviewed the ratio of acetate: propionate: butyrate and reported that it varied between 75:15:10 and 40:40:20. France & Dijkstra (2005) reported that the ratio of acetate: propionate: butyrate generated by high fibre diets is generally in the region 70:20:10. This ratio is highly variable and depends on the time measured after feeding (Bergman, 1990). It has been demonstrated that the total VFA and individual concentrations attain a peak 2 to 4 hours after feeding. However, in most cases, acetate accounts for the majority of the VFAs. The pH of rumen fluid is also known as a contributory factor to the proportion of VFA components (Dijkstra, 1994). A higher pH is favourable to microbes which produce acetate and butyrate, whereas a lower pH value is suitable for microbes which yield propionate (Bergman, 1990; Dijkstra, 1994). Moreover, high fibre-diet stimulates an increase in salivation through the rumination process which results in a rise in pH of the rumen liquor and a subsequent increase in acetate and butyrate. The pH of the rumen normally ranges from 5.8 to 6.8, however, with rich starch diets and fast fermentation, the pH can be lower than 5 (Bergman, 1990), a situation that can lead to acidosis and associated effects.

Ammonia

Ammonia which is the main source of nitrogen for microbial protein synthesis of many bacterial species, is the end-product of proteolysis in the rumen. Ammonia concentration in the rumen fluid is strongly dependent on diet and normally reaches a peak at 2-4 h after feeding (Litherland *et al.*, 2000; Wang *et al.*, 2009). Previously, it was demonstrated that the optimal level of ammonia concentration for microbial growth ranged from 20 to 40 mg/l (Satter & Slyter, 1974; Slyter *et al.*, 1979). Leng (1990) reported that under tropical conditions, the optimum ammonia concentration for digestibility is around 100 to 200 mg/l. Different sources of protein were observed to have a significant effect on ammonia concentration (Litherland *et al.*, 2000; Nivea Regina de Oliveira Felisberto *et al.*, 2011; Wang *et al.*, 2009). This is dependent on the proportion of rumen degradable protein which generates larger amounts of ammonia. Moreover, increased

concentrate level in the diets leads to an increase in ammonia concentration (Cantalapiedra-Hijar *et al.*, 2009; Cerrillo *et al.*, 1999).

2.4 Plasma metabolites

Plasma metabolites have been used as integrated indicators to assess animal nutrient supply especially in intensive grazing systems where feed nutrient quality depends on prevailing season and climate. Conventional methods such as body condition score (BCS) and liveweight are variable and depend on the physical condition of the animal (Pambu-Gollah *et al.*, 2000; Žubčić, 2001). Through the relationship between BCS and plasma metabolite concentration of lambs, Caldeira *et al.*, (2007) concluded that indicators such as glucose, non-esterified fatty acids and insulin could be used to evaluate the changes in energy, and testing indices like albumin and urea to assess protein status. These indices can also be used to evaluate the physiological and health status of goats (Daramola *et al.*, 2005). Rumosa *et al.*, (2010) observed a negative linear relationship between parasites' burden and plasma parameters.

Plasma profiles have also been used to test the adverse impacts of anti-nutritional factors like tannin or mimosine on metabolism. Rongzhen *et al.*, (2011) tested the effect of different levels of tea catechins on plasma metabolites and found that supplementation at 2,000 mg of tea catechins/kg of feed was not detrimental to goats. Similarly, a mixture of tree legumes (*Leucaena leucocephala*-*Morus alba*-*Tectona grandis*) at a ratio of 2:1:1 used to replace up to 50% of conventional proteins fed to goats yielded results that were consistent with biochemical indicators in the normal range of healthy goats (Anbarasu *et al.*, 2002). Besides assessing chemical composition, digestibility and nitrogen balance, other researchers (Belewu & Ojokomaro, 2007; Merkel *et al.*, 2001; Turner *et al.*, 2005) have also tested the effect of different forages or tree leaves on the health status of goats.

Some studies have reported breed differences in plasma metabolite concentrations (Mbassa & Poulsen, 1992), but Sahluet *et al.*, (1993) found that there were no significant differences in plasma parameters between Nubian, Alpine and Angora goats fed different levels of protein.

2.5 Meat quality

It is well documented that goat meat is lean, has low fat and cholesterol contents compared to other red meat types (Babiker *et al.*, 1990; Tshabalala *et al.*, 2003) and has a healthier fatty acid profile than lamb (Lee *et al.*, 2008a). Goat meat and its components vary widely due to differences in breed (Ameha Sebsibe *et al.*, 2007; Dhanda *et al.*, 1999; Dhanda *et al.*, 2003; Kadim *et al.*, 2003; Simela *et al.*, 2004), age (Beserra *et al.*, 2004), sex (Mahgouba *et al.*, 2002), body weight (Dhanda *et al.*, 2003; Todaro *et al.*, 2002), nutrition (Atti *et al.*, 2004; Haddad, 2005; Madruga *et al.*, 2008; Mushi *et al.*, 2010; Ryan *et al.*, 2007) and pre-slaughter condition (Kadim *et al.*, 2006). However, the focus for this literature review is on the effect of plane of nutrition on goat meat quality.

2.5.1 Carcass composition

2.5.1.1 Carcass weight and dressing percentage

Carcass weight is the best index to measure meat production because goat meat is sold in the market on weight basis. Therefore, the dressing percentage, which is the proportion of the carcass weight and the full or empty body weight, plays a crucial role in the assessment of meat yield.

In general, these two indices are the most variable between breed, sexes, age and nutrition. The carcass weight and dressing percentage in goats are generally between 10 kg to 32 kg and 39% - 52%, respectively (Mahgoub *et al.*, 2012).

Hot carcass weights ranging from 11.9 to 13.4 kg and dressing out percentages based on empty body weights between 53 and 57%, in which the final body weight ranged from 29.3 to 33.1 kg

were reported in one year old Omani goats (Kadim *et al.*, 2003). Ameha Sebsibe *et al.*, (2007) observed significant differences in dressing percentage ranging from 54.3% to 55.8% between three Ethiopian goat breeds in which live body weight ranged from 18 to 20 kg. Dhanda *et al.*, (2003) also found significant differences in dressing percentage between 6 goat breeds, ranging from 51 to 54%.

Cross breeding between indigenous and exotic goat breeds with the sole purpose of improving meat productivity and quality has been implemented in different parts of the world (Assan, 2012; Beserra *et al.*, 2004; Ding *et al.*, 2010; Shrestha & Fahmy 2007). The results have been unanimous in concluding that crossbreeding helps in improving carcass traits for a better commercial value of goat meat.

Within breeds, the impact of plane of nutrition has been demonstrated to be mainly reflected in the carcass weight and dressing percentage indices. Haddad (2005) found that increasing the forage: concentrate ratios from 60:40 to 15:85 in the diets resulted in significant increases in hot carcass weight from 9.1 kg to 12.9 kg, cold carcass weight from 8.9 to 12.1 kg in and dressing percentage from 43.6 to 47.5%. The same trend was demonstrated by Liméa *et al.* (2009) in goats supplemented with concentrates at the rate of 340 g/head/day. Significant linear increases in carcass weight from 9 to 13 kg, and dressing percentage from 42% to 51% were observed. Similarly, Safari *et al.*, (2009) suggested that supplementing goats with up to 66% of concentrates resulted in a 3 kg heavier carcass weight and higher dressing percentage than in goats fed non-concentrate diets. These findings are in agreement with the results of Ameha Sebsibe *et al.*, (2007) when the concentrate : roughage ratios were raised from 50:50 to 80:20. Similarly, Ryan *et al.*, (2007) reported significant differences in carcass weight and dressing percentage of Boer crossbred goats when the amount of concentrates shifted from 50% to 90% in the diets. In general, increasing the level of concentrates in diets results in significant increases in carcass weight and dressing percentage.

2.5.1.2 Tissue Dissection

The main tissues in the carcass are muscle, fat and bone. Muscle is the most important component in the carcass as it is totally edible. Goats produce leaner meat and less fat in their carcasses than sheep because fat is mainly located around the viscera and is trimmed out as offal (Colomer-Rocher *et al.*, 1992; Tshabalala *et al.*, 2003). The preferential order of adipose depots in goats is visceral – followed by intermuscular, subcutaneous and intramuscular fat (Webb *et al.*, 2005). Adipose tissue develops late in life; hence it accumulates mainly as a component of the mature body weight.

Muscle, bone and fat proportions in the carcass are highly variable chiefly due to differences in nutrition levels or slaughter weight. Fat is well known as the most variable tissue in the carcass. The proportion and location of fat determine the quality and commercial value of meat. Liméa *et al.*, (2009) concluded that visceral fat accumulated significantly following an increase in concentrate levels from zero to 310 g/head/d, however, there was no excessive fat, and the goats had a good body conformation and heavy carcass weight. In another study, Safari *et al.*, (2009) fed Small East African goats at four levels of concentrates, namely 0, 33%, 66% and 100% of *ad libitum* concentrate intake. The results showed that the concentrate-supplemented goats had a 9% higher carcass fat content than goats with no concentrates in the diet. The proportion of muscle was not different between treatments, with the figures ranging from 65% to 68%. However, the percentage of bone in the 100% concentrate treatment was 8.5% less than in the control treatment. The same treatments were tested in Small East African x Norwegian crossbred goats by (Mushi *et al.*, 2009). Their findings were in agreement with the previous research except for the significant difference in the proportion of muscle between treatments, with percentages ranging from 60 to 65%. Generally, when the level of concentrate in the diet increases, it results in heavier carcass weight, hence more muscle and less fat. In other words, the proportion of bone in the carcass reduces when the body weight increases, fat percentage reduces as muscle accretion becomes a priority.

Besides concentrate levels, the impact of dietary crude protein on the carcass components was investigated by Atti *et al.*, (2004) when they supplemented goats with concentrates containing

10%, 13% and 16% CP. They found no differences in muscle, bone and adipose tissue mean weights between treatments. The interaction between protein and energy is common, however, it has not been widely investigated as the method of diet formulation has a confounding effect (Goetschet *et al.*, 2011).

2.5.2 Meat Quality Characteristics

2.5.2.1 Meat pH

The pH of meat is an important quality trait which influences meat colour, water holding capacity and tenderness (Kadim *et al.*, 2006; Watanabe *et al.*, 1996) and determines the commercial value of meat and consumer preferences. Glycogen stored within the muscle is anaerobically metabolised after slaughter resulting in the accumulation of H^+ hence the lower post mortem pH value of muscle. Kannan *et al.*, (2006) observed a significant decline in *Longissimus dorsi* pH value when the ageing time increased from 0 to 24 h. The pH value was around 6.8 at the time of slaughter and decreased to approximately 5.6 after 24 h post mortem. Protein and energy treatments were found not influence pH value (Abdullah & Musallam, 2007). The pH values of different goat breeds and individual muscles have been reported to vary significantly (Kadim *et al.*, 2003) in which the muscle of Batina goats had higher pH than those Dohfari and Jabal Akdhar goats.

The pH value of muscle is variable mainly due to pre-slaughter stress that leads to a depletion of muscle glycogen before slaughter (Kadim *et al.*, 2006). In general, pH value has been used to assess meat quality because of its links to muscle tenderness. PH value of meat is known to decrease with ageing.

2.5.2.2 Meat colour

Meat colour is a sensory index in which consumers make an assessment of meat quality. Colour is created by the concentration of myoglobin, muscle structure and the ability of the muscle to absorb or scatter incident light. The measurement of colour includes two basic methods; visual and instrumental assessments. Instrumental analysis using the Hunter scale consists of three

parameters, namely, L (lightness), a (redness) and b (yellowness). It is less subjective and is a popular method of meat colour assessment.

Meat colour is affected by factors like breed (Dhanda *et al.*, 1999; Kadim *et al.*, 2003; Madruga *et al.*, 2008), age (Ding *et al.*, 2010; Simela *et al.*, 2004) and type of muscle (Kadim *et al.*, 2003). It is also well documented that nutrition levels have significant effects on meat colour index. Ryan *et al.*, (2007) conducted an experiment utilising different levels of concentrates and showed that goats fed concentrates had greater muscle values of a and b parameters than those fed range diets, while the L parameter was 38 and not significantly different between diets. Furthermore, Lee *et al.*, (2008b) observed that goats fed alfalfa hay alone had higher values of L and b than those fed concentrate diets and the values were not different between treatments. Energy levels have also been reported to have no effect on meat colour (Abdullah & Musallam, 2007).

2.5.2.3 Meat chemical composition

Mahgoub *et al.*, (2012) conducted an extensive review and reported that goat meat has less fat content than lamb and beef, but the same proportion of protein. Different researchers have investigated various muscles from different anatomical sites, but it is difficult to compare the results given the broad spectrum of nutritional, breed and age differences between the experimental animals. Generally, carcass chemical composition varies mainly due to genotype (Ding *et al.*, 2010) and age (Beserra *et al.*, 2004). The effect of plane of nutrition on meat chemical composition is inconsistent from one research investigation to another. Atti *et al.*, (2004) found that goats fed medium levels of crude protein at 13% of dry matter had greater protein and less fat percentages in the *Longissimus dorsi* and *Supraspinatus* muscles than those fed higher crude protein diets. Increased levels of concentrate in the diet have been reported to lead to an increase in fat in the *Longissimus dorsi* muscle of goats, but the crude protein content did not differ between treatments (Mushi *et al.*, 2009). This is in agreement with the observations of Safari *et al.*, (2009). However, Liméa *et al.*, (2009) did not find any difference in the chemical composition of the shoulder muscle between varying levels of protein and energy in different concentrate diets. Agnihotri *et al.*, (2006) also did not observe any difference in chemical

composition in the *Longissimus thoracis* muscle of goats fed various levels of protein and energy. Madruga *et al.*, (2008) also found no treatment differences in the chemical composition of the *semi-membranosus* muscle of goats on two feeding levels: *ad libitum* and restricted feeding of 63% of the total feed consumed.

2.5.3 Fatty acid profiles

It is widely recognised that the fatty acid (FA) profile of goat meat plays an important role in human health. There have been many investigations into the factors influencing goat meat fatty acid composition (Banskalieva *et al.*, 2000; Mushi *et al.*, 2009; Ryan *et al.*, 2007).

Saturated fatty acids (SFAs) contain no double bonds between the carbon atoms, and are considered unhealthy for human consumption except for stearic acid (C18:0). In contrast, the unsaturated fatty acids (USFAs) have at least one double bond in their backbone of carbon atoms, and are believed to have positive effects on human health. FAs vary between species, especially ruminant and non-ruminant animals. The main reason for the difference is due to the activity of microbes in the rumen of ruminants. USFAs are susceptible to biohydrogenation by microbes in the rumen, thus increasing the amount of SFAs that pass into the intestine, absorbed into the blood stream and deposited in tissues. This results in the higher level of SFAs in ruminant meat.

FA profile in goat meat is variable depending on several factors; however, the plane of nutrition has been reported as having the most significant impact. The FA profile of fat in different anatomical sites such as intramuscular fat in muscles, internal fat and subcutaneous fat, have also been reported to vary. Ryan *et al.*, (2007) found that goats fed concentrates had greater levels of SFAs and mono USFAs, but lower levels of n-3 FA in the *Longissimus dorsi* muscle compared with goats that grazed in the rangelands. This is in agreement with the research findings of Lee *et al.*, (2008b), which compared goats fed hay alone and those supplemented with concentrates. However, Mushi *et al.*, (2009) reported very limited differences in the FAs of the *Longissimus dorsi* muscle from goats varying in the level of concentrate consumption.

2.6 Summary of identified knowledge gaps and research objectives

- The effect of concentrates on meat quality of goats varies between publications, especially in meat fatty acid composition. Moreover, increased concentrate levels in the diets is believed to decrease fibre digestibility with subsequent adverse impacts on rumen characteristics. However, there are inconsistencies in published results making it harder to extrapolate findings to the particular goat production systems in Vietnam, hence the need to test the effect of concentrate supplementation using locally available ingredients and common breed of goats.
- The best level of concentrate supplementation under Vietnamese smallholder goat production system is largely vague and needs quantification.
- Meat quality studies evaluating the fatty acid composition of the *Longissimus dorsi* in Bach Thao goats are at best, inadequate and largely unknown.

Therefore, the objectives of this research to fill the identified knowledge gaps are:

- To evaluate the effects of mixed concentrates using local feed ingredients on growth, digestibility, rumen fermentation, carcass and meat quality attributes of Vietnamese Bach Thao goats.
- To determine the optimum level of supplementation for the greatest growth performance and meat quality responses in Bach Thao goats.

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Chapter 3: Productive performance, rumen fermentation and plasma metabolites of concentrate-supplemented Bach Thao goats in Vietnam

Q.H. Nguyen^{ab}, P. A. Lane^a, V.H. Nguyen^b, D. Parsons^a, B.X. Nguyen^b, A.E.O. Malau-Aduli^{a*}

^aSchool of Land and Food, Tasmanian Institute of Agriculture, University of Tasmania, Private Bag 54 Hobart, TAS 7001, Australia.

^bFaculty of Animal Sciences, Hue University of Agriculture and Forestry, Hue City, Vietnam.

Abstract

Twenty-five Bach Thao bucks (7 months old and 20.9 ± 0.3 kg body weight) were used to quantify the effect of concentrate supplementation on growth performance, rumen volatile fatty acid profile, digestibility and plasma metabolites. Goats were allocated into five treatment groups of varying levels of concentrate supplementation: Control (*ad libitum* access to elephant grass), 0.6%C (control plus 0.6% of concentrates), 1.2 %C (control plus 1.2% of concentrates), 1.8%C (control plus 1.8% of concentrates), and 2.4%C (control plus 2.4% of concentrates) as a percentage of liveweight on dry matter basis. Growth and feed intake were measured in a nine - week feeding trial period after three weeks of initial adaptation. *In vivo* digestibility was assessed in the 10th week by the total faecal collection method. There were significant increases in average daily gain (ADG), feed intake and digestibilities of dry matter (DM), organic matter (OM) and crude protein (CP) as dietary concentrate levels increased. However, digestibility of neutral detergent fibre (NDF) was not different between the concentrate - supplemented groups. Pre-feeding ammonia concentration in rumen fluid was not different between treatments, but 4 hours after feeding, significant differences were detected. The values of ammonia ranged from 100-200 mg/l at both times of measurement. Rumen fluid pH values were not different 4 hours post-feeding. Volatile fatty acid concentrations of propionate and butyrate increased with increasing levels of concentrates consumed, in contrast to decreased acetate concentration. In conclusion, this study clearly demonstrated that increasing levels of concentrate supplementation of Bach Thao bucks up to 1.8% of liveweight on a DM basis resulted in the greatest improvement in ADG, feed intake and nutrient digestibility, thus confirming the tested hypothesis that increased level of concentrate supplementation will improve productive performance of goats without an adverse effect on rumen fermentation and nutrient digestibility.

Key words: Bach Thao goats, concentrates, digestibility, ammonia, volatile fatty acids.

3.1. Introduction

Concentrates have been used in ruminant livestock feeding to meet the growing demand for goat meat as the human population increases. The role of concentrates in goat rations is to increase dietary energy density, protein quality, feed efficiency and balance between starch and forage. However, concentrate supplementation can also lead to depression of rumen fluid pH which in turn reduces fibre digestibility or causes acidosis when the level of supplementation is excessive. Therefore, there is the need to determine the optimal amount of concentrates that smallholder goat farmers can efficiently use for dietary supplementation.

There are several investigations on the use of concentrates and varying levels of dietary supplementation in goats (Cantalapiedra-Hijar *et al.*, 2009; Cerrillo *et al.*, 1999; Haddad, 2005; Urge *et al.*, 2004). However, these studies utilised feed ingredients that are not locally available and the reported nutrient digestibility and rumen fermentation results are impractical to extrapolate to the Vietnamese goat production system. The environmentally harsh mountainous areas of Vietnam where a large proportion of goats are raised are characterised by poor quality feeds. This limits the herd size of goats kept by most smallholder farmers to 5-7 head (Mui, 2006). The area of free grazing pasture is reducing rapidly and the feed quality does not meet the nutrient requirement of goats for high production. Therefore, the intensive or semi - intensive farms with concentrate supply seem to be more economically efficient (Haddad, 2005). Confinement systems with cultivated or cut and carry native grass and concentrate supplements have been created for cattle production in Vietnam with positive improvements in efficiency of production (Nguyen *et al.*, 2008). For a better economic efficiency of feed utilisation, local ingredients also can be used as sources of concentrates to supplement goats.

The objective of this investigation was to evaluate the effect of varying levels of concentrate supplementation on growth performance, digestibility, rumen fermentation and plasma metabolites of Bach Thao goats. This research was also conducted to test the hypothesis that increased level of concentrate supplementation will result to greater productivity without any adverse impact on rumen fermentation indices and digestibility.

3.2. Materials and Methods

3.2.1. Animals and housing

The experiment was conducted at Hue University of Agriculture and Forestry Farm in Thua Thien, Hue Province (16°00' to 16°48' latitude, 107°48' to 108°12' longitude) in Vietnam. Twenty-five Bach Thao bucks, approximately 7 months old, of initial liveweight 20.3 ± 0.9 kg (M \pm S.D.) were used for the experiment. On arrival, they were treated with Ivermectin (2 ml/25 kg BW) for internal and external parasites. They were individually housed in pens (1.5 x 0.75 m) with separate feeding troughs and had unrestricted access to fresh drinking water.

3.2.2. Feeding trial

The experimental animals were given a three-week adaptation period, after random allocation into 5 treatment groups (5 bucks per treatment) in a completely randomized design and fed for six weeks. The five treatment groups were: Control (*ad libitum* access to elephant grass (*Pennisetum purpureum*)), 0.6 %C (control plus 0.6% of concentrates), 1.2 %C (control plus 1.2% of concentrates), 1.8 %C (control plus 1.8% of concentrates), and 2.4 %C (control plus 2.4% of concentrates) as a percentage of liveweight on dry matter basis.

The concentrate ration was formulated to contain 16% CP. It was thoroughly mixed and fed to the goats twice daily before the fresh elephant grass was given. The quantity of concentrate was adjusted weekly based on the goats weekly liveweight changes. The chemical composition of elephant grass and mixed concentrates are presented in Table 3.1.

Table 3.1 The proportions of ingredients (g/kg DM) and nutrient contents of the concentrates and elephant grass.

Ingredient		Proportion (g/kg DM)
Rice bran		323.4
Maize		333.2
Fishmeal		127.4
Cassava powder		196
Mineral – Vitamin		10
Salt		10
Nutrient composition (%)		
Nutrient (% as DM basis)	Mixed concentrates	Elephant grass
Dry matter	87.2	17.6
Crude protein	15.7	9.2
Organic matter	91.0	89.4
Neutral detergent fibre	30.9	68.7
Acid detergent fibre	5.8	37.5

Every morning feed residuals were weighed and recorded before new feed rations were offered to the animals. Feed samples were analysed weekly for chemical composition. The liveweight of animals was measured weekly to calculate the weight gain and adjust the concentrate supplementation levels. After six weeks of experimentation, nutrient digestibility was measured using the total faecal collection method.

3.2.3. Digestibility trial

The last 7 days of the feeding trial were used for the digestibility evaluation in which feed sub-samples, feed residuals, and voided faeces were collected. Each sample fraction was thoroughly mixed and weighed daily at 0800hrs, and a sub sample collected, dried at 60°C and stored for subsequent analysis. About 10% of the faeces were collected and stored at -20°C. The frozen

faecal samples were thawed, mixed, and duplicate sub-samples from each goat were dried at 60°C for 48 hours and ground through a 1mm screen before laboratory analysis.

3.2.4. Blood and rumen fluid sample collection

3.2.4.1. Blood sample collection

Blood samples were collected via jugular venipuncture from each goat before and after the feeding trial. Two ml of blood samples from each goat were taken out and deposited in anticoagulant containing plastic tubes. Samples were centrifuged to separate the plasma from the blood for biochemical analysis using an Automatic Biochemical analyser (HIT 717, Hitachi, Japan). The parameters measured included Plasma Glutamic Oxaloacetic Transaminase (PGOT), Plasma Glutamic Pyruvic Transaminase (PGPT), glucose, urea, creatinine, protein, albumin and cholesterol.

3.2.4.2. Rumen fluid sample collection

On the last day of the feeding trial, 50ml of rumen fluid from each buck was taken using a stomach tube at 0 and 4 hours after feeding the concentrates. Thereafter, the rumen fluid was filtered through a muslin cloth to remove coarse particles, centrifuged at 3000 rpm and, samples then stored at -20°C for subsequent analysis.

3.2.5. Chemical analysis of samples

Nitrogen concentration in the feeds and faeces were determined using the Kjeltec 8200 (Foss, Sweden) following the Kjeldahl method. Crude protein concentration was calculated as N x 6.25. Neutral Detergent Fibre (NDF) was analysed using the Fibertec 1020 (Foss, Sweden) as described by Van Soest *et al.* (1991). Dry matter (DM), Ash and Ether extract (EE) were determined according to AOAC (1990). Rumen fluid was immediately measured for pH using a pH meter (Schott, Germany) and analysed for volatile fatty acids using the standard Gas Chromatography (GC) method.

3.2.6. Statistical analysis

Experimental data were analysed using the repeated measures analysis of variance in General Linear Model Procedure of SAS (2009). The model included the fixed effects of treatment and a random term. Duncan's multiple range tests were used for separation of means.

3.3. Results

3.3.1. Nutrient intake and average daily gain

As the levels of concentrates consumed increased from 0 to 495 g/d, there was a decrease in grass intake from 429 to 284 g/d (Table 3.2). As a result, the total dry matter intake increased significantly ($P<0.05$) from 429.1 g/d in the control treatment to 779.2 g/d in the 2.4 %C treatment. There was also an increase ($P<0.05$) in average daily gain when the proportion of concentrates in the diets increased. The highest ADG value of 150 g/d was recorded in treatments 1.8 %C and 2.4 %C and the lowest ADG of 2.4 g/d was observed in the control treatment.

Table 3.2 Feed intake (g) and average daily gain (g/day) of goats fed varying levels of concentrate (Least Squares Means \pm SD).

Parameters	Experimental diet				
	Control	0.6 %C	1.2 %C	1.8 %C	2.4 %C
Grass intake	429.0 \pm 62.1 ^a	415.7 \pm 36.5 ^a	376.5 \pm 32.5 ^a	302.8 \pm 58.1 ^b	284.1 \pm 50.9 ^b
Concentrate					
Intake	-	122.8 \pm 9.3	252.5 \pm 10.3	378.9 \pm 55.1	495.2 \pm 36.7
Total DM intake	429.1 \pm 62.1 ^a	538.5 \pm 43.8 ^b	629.1 \pm 32.3 ^c	681.7 \pm 105.8 ^c	779.2 \pm 31.5 ^d
ADG	2.4 \pm 5.3 ^a	21.4 \pm 17.7 ^a	73.8 \pm 31.9 ^b	150 \pm 37.3 ^c	150 \pm 37.3 ^c

Note: ADG = average daily gain

^{a-c}Means in the same row with different superscripts are significantly different ($P<0.05$)

3.3.2. Nutrient digestibility

The digestibility of DM, OM and CP increased significantly ($P<0.05$) as the level of concentrate in the diets increased (Table 3.3). The DM digestibilities of concentrate – supplemented groups were significantly higher than in the control group, in which the 1.8%C and 2.4%C treatments resulted in the highest values of 80%. Organic matter and DM digestibility values followed the same trend ranging from 63.2% to 80.2%. Similarly, the greatest CP digestibility was in treatments 1.8 %C and 2.4 %C (76.5% and 76.8%, respectively), and these were significantly higher than in other treatments. The digestibility of NDF in the control treatment was significantly less than in the supplemented groups, except for treatment 1.2%C. However, there were no differences between the concentrate-supplemented treatments.

Table 3.3 Apparent nutrient digestibility of goats fed varying levels of concentrates (Least Square Means \pm S.D.).

Digestibility (%)	Experimental diet				
	Control	0.6 %C	1.2 %C	1.8 %C	2.4 %C
DM	59.4 \pm 7.2 ^a	68.2 \pm 5.2 ^b	72.8 \pm 3.4 ^b	80.6 \pm 3.0 ^c	80.8 \pm 5.5 ^c
OM	63.2 \pm 3.9 ^a	71.8 \pm 4.5 ^b	72.0 \pm 2.0 ^b	78.3 \pm 3.2 ^c	80.2 \pm 2.5 ^c
CP	68.6 \pm 2.2 ^a	70.8 \pm 4.9 ^a	69.6 \pm 4.0 ^a	76.5 \pm 4.5 ^b	76.8 \pm 1.8 ^b
NDF	64.4 \pm 3.1 ^a	69.3 \pm 4.8 ^{bc}	65.0 \pm 3.4 ^{ab}	69.0 \pm 2.9 ^{bc}	69.8 \pm 1.1 ^{bc}

^{a-c}Means in the same row with different superscripts are significantly different ($P<0.05$)

Note: DM = dry matter, OM = organic matter, CP = crude protein, NDF = Neutral Detergent Fibre.

3.3.3. Rumen Fluid Ammonia Concentration and pH

Values for pH values before feeding were significantly different between treatments. The 1.2 %C, 1.8 %C and 2.4 %C treatments were higher ($P<0.05$) than the control and 0.6 %C treatments with pH values of 6.5, 6.6 and 6.6, respectively (Table 3.4). After 4 hours of feeding, there were no significant differences between the treatments with pH values ranging from 5.9 to 6.3. Pre-feeding ammonia concentration was not statistically different between treatments, with the values ranging from 103.9 to 148.9 mg/l. However, after 4 hours of feeding, the greatest

value of 229.2 mg/l was recorded in treatment 1.2 %C, which was significantly ($P<0.05$) higher than the control treatment. There were no significant differences between the concentrate-supplemented groups of ammonia concentration and pH value of rumen fluid before and after 4 hours of feeding (Table 3.4).

Table 3.4 Ammonia concentration and pH value (Least Squares Means \pm SD) of rumen fluid before and after 4 hours of feeding.

Parameters	Experimental diet				
	Control	0.6 %C	1.2 %C	1.8 %C	2.4 %C
pH before feeding	6.1 \pm 0.3 ^a	6.0 \pm 0.1 ^a	6.5 \pm 0.1 ^b	6.6 \pm 0.1 ^b	6.6 \pm 0.1 ^b
pH after feeding	6.0 \pm 0.4	5.9 \pm 0.2	6.3 \pm 0.1	5.9 \pm 0.3	6.2 \pm 0.3
Ammonia before feeding (mg/l)	103.9 \pm 18.5	148.9 \pm 52.6	139.2 \pm 20.7	106.5 \pm 72.3	125.8 \pm 54.8
Ammonia after 4h of feeding (mg/l)	117.0 \pm 33 ^a	198.0 \pm 62.1 ^{ab}	229.2 \pm 56.2 ^b	146.1 \pm 89.8 ^{ab}	152.8 \pm 63.4 ^{ab}

^{a-c}Means in the same row with different superscripts are significantly different ($P<0.05$)

3.3.4. Rumen Volatile Fatty Acid Concentrations

The change in volatile fatty acid concentration followed a similar trend before and after 4 hours of feeding (Table 3.5). Acetate concentration reduced ($p<0.05$) while propionate and butyrate percentages increased ($p<0.05$) with increasing concentrate levels in the diets. Before feeding, acetate proportion in the control and 0.6 %C treatments recorded the highest values (76.0% and 74.8%, respectively) while the lowest value of 59.1% was recorded in the 2.4 %C treatment. Conversely, the highest propionate percentage was in the 2.4 %C treatment (28.7%), the lowest butyrate percentages were in the control and 0.6 %C treatments (5.8% and 8.4%, respectively), which were significantly ($P<0.05$) lower than in the other treatment groups. Similarly, after 4 hours of feeding, the highest acetate concentration was found in the control and 0.6 %C treatments (72.3% and 68.8%, respectively) which were higher ($P<0.05$) than the values in other treatments. Propionate values in treatments 1.8 %C and 2.4 %C were higher ($P<0.05$) than in

other treatments, at 37.1% and 35.5%, respectively. The lowest proportion of butyrate was in the control treatment (6.7%) which was lower ($P<0.05$) than in the supplemented groups which ranged from 10.5% to 15.1%.

Table 3.5 VFA profile (%) of rumen fluid before and 4 hours after feeding.

Parameters		Control	0.6 %C	1.2 %C	1.8 %C	2.4 %C
Before feeding	Acetate	76.0±2.4 ^a	74.8±3.2 ^a	63.0±5.2 ^b	61.2±4.6 ^b	59.1±9.1 ^b
	Propionate	18.2±1.6 ^a	16.8±3.4 ^a	21.1±2.7 ^a	23.5±5.6 ^{ab}	28.7±8.6 ^b
	Butyrate	5.7±2.0 ^a	8.4±2.2 ^a	15.8±4.4 ^b	15.4±3.3 ^b	12.2±1.8 ^b
4h after feeding	Acetate	72.3±3.2 ^a	69.8±4.1 ^a	58.0±5.8 ^b	50.3±5.2 ^c	53.2±5.8 ^{bc}
	Propionate	21.1±2.9 ^a	19.7±3.5 ^a	26.9±4.6 ^a	37.1±6.7 ^b	35.5±7.7 ^b
	Butyrate	6.7±1.4 ^a	10.5±1.5 ^b	15.1±2.8 ^c	12.6±2.0 ^{bc}	11.4±2.5 ^b

^{a-c}Means in the same row with different superscripts are significantly different ($P<0.05$)

3.3.5. Plasma Metabolites

The values of plasma metabolites before the experimental period were highly variable (Table 3.6). Plasma Glutamic Oxaloacetic Transaminase (PGOT) and glucose concentrations were lower than the reference range in some treatments. Creatinine and cholesterol concentrations were lower than reference values in all treatments. Plasma Glutamic Pyruvic Transaminase (PGPT) values were higher than the normal range in all treatments (Table 3.6). However, after the experimental period, most indices were within the normal range, except for PGOT and creatinine which were lower and PGPT values higher than the reference values.

Table 3.6 Plasma metabolites before and after the experimental period.

Parameters	Experimental diet					Reference value
	Control	0.6 %C	1.2 %C	1.8 %C	2.4 %C	
Glucose BF (mmol/l)	2.2±0.5	2.8±0.4	2.5±0.3	2.7±0.4	2.9±0.4	2.8-4.2
Glucose AF (mmol/l)	2.5±0.4 ^a	2.7±0.3 ^{ab}	2.9±0.2 ^{ab}	3.1±0.5 ^b	2.9±0.3 ^{ab}	2.8-4.2
PGOT BF (U/l)	207.8±175.4	129.8±15.9	118.2±16.2	155.2±98.1	194.0±130.5	167-513
PGOT AF (U/L	124.8±27.6	127.4±57.8	114.0±15.2	119.0±47.4	107.0±23.1	167-513
PGPT BF (U/L	43.6±11.5	29.2±2.3	25.0±5.3	32.8 ±10.3	34.8±12.8	6-19
PGPT AF (U/L	28.6±4.9	32.4±6.4	42.0±23.3	27.2±12.7	25.6±1.7	6-19
Urea BF (mmol/l)	5.4±0.5	6.0±0.5	6.2±1.2	7.5±3.5	6.4±2.2	3.6-7.1
Urea AF (mmol/l)	5.2±0.5	4.9±0.7	4.9±0.7	4.3±0.9	5.9±1.8	3.6-7.2
Creatinine BF (µmol/l)	74.4±7.8	64.4±7.1	63.0±10.4	75.0±21.7	64±11.9	88.4-159
Creatinine AF (µmol/l)	66.6±6.9	64.6±10.8	64.0±13.8	64.8±8.4	72.0±15.6	88.4-159
Protein BF (g/l)	67.2±4.8	66.6±4.2	64.4±1.4	70.4±2.8	66.6±3.1	64-70
Protein AF (g/l)	71.2±5.3	64.2±7.8	65.2±3.1	68.0±4.6	66.6±2.4	64-70
Albumin BF (g/l)	44.2±0.8	42.2±2.3	38.4±3.7	44.6±3.1	42.0±2.5	27-39
Albumin AF (g/l)	30.0±3.3	28.2±3.0	29.4±1.3	29.2±4.7	32.0±0.7	27-39
Cholesterol BF (mmol/l)	1.5±0.6	2.0±0.5	0.9±0.6	1.7±0.5	1.4±0.3	2.1-3.4
Cholesterol AF (mmol/l)	2.2±0.6	2.0±0.3	2.7±0.4	2.2±0.4	2.4±0.5	2.1-3.4

Note: BF: before experimental period, AF: After experimental period, PGOT: Plasma Glutamic Oxaloacetic Transaminase, PGPT: Plasma Glutamic Pyruvic Transaminase

Reference values (Kaneiko *et al.* 2008)

^{a-c} Means in the same row with different superscripts are significantly different (P<0.05)

3.4. Discussion

3.4.1. Feed intake and liveweight gain

In this investigation, feed intake increased when goats were fed high levels of concentrates in the diets. This is in agreement with Haddad (2005) who observed an increase in feed intake when the concentrate : forage ratios rose from 40:60 to 85:15. In present study, there was a substitution between grass and concentrate intake in which grass intake reduced when concentrate consumption increased. This could be explained by the higher palatability and smaller volume of concentrates compared to forages. Moreover, grains produce less heat than forages (Mahgoub *et al.*, 2000) and this has an effect on feed intake of goats in hot climatic regions. The goats were able to consume comparatively more concentrates than when fed grass only, thus increasing the total dry matter intake and consequently the ADG. Although the total DM intake of goats in treatment 2.4 %C was greater than in treatment 1.8 %C, both treatments had the same average daily gain (ADG)(150 g/d), indicating that there is a limit to the benefit of substituting grass with concentrates. In terms of economic efficiency, it would be more beneficial for Bach Thao goat farmers to supplement at 1.8 %C and yet achieve the same growth levels as 2.4 %C. Other researchers have observed similar results of increased feed intake and ADG as concentrate levels in the diets increased (Haddad 2005; Mushi *et al.*, 2009; Safari *et al.*, 2009; Salim *et al.*, 2002).

3.4.2. Nutrient Digestibility

When the proportion of concentrates in the diets increased, it resulted in higher DM, CP and OM digestibilities. This is consistent with the findings of other investigators (Cantalapiedra-Hijar *et al.*, 2009; Haddad, 2005). The results for apparent digestibility of DM, OM and CP in the current experiment ranged from 59 to 81% and were higher than the 57-70% range reported by Haddad (2005). This might be due to differences in the type of ingredients used in ration formulation which has been previously reported by Cantalapiedra-Hijar *et al.*, (2009) as a causal source of variation. It is well established that low pH of rumen fluid depresses fibre digestion (Cerrillo *et al.*, 1999; Grant & Mertens, 1992; Haddad, 2005). However, in this experiment, there was no difference in pH value between treatments after 4 hours of feeding. This might be explained by the quick passage rate of concentrates through the rumen as the concentrates were offered and

consumed before grass. Thus, no significant difference in NDF digestibility between the concentrate-supplemented groups was found.

3.4.3. Rumen Fermentation

In the current study, the ammonia concentration (103.9 – 229.2 mg/l) was in agreement with the 100-200 mg/l range under tropical conditions (Leng, 1990). Ammonia concentrations in the 0.6 %C and 1.2 %C treatments were higher than the other treatments at both points of measurement. This could be explained by the concentrate to forage ratios which the animals consumed. As the levels of consumed concentrates increased, it meant a greater amount of CP was consumed, thus leading to a faster rate of passage through the rumen. Therefore, in treatments 1.8 %C and 2.4 %C, where goats consumed the highest amount of concentrates compared with the other treatments, rumen retention time was comparatively shorter than in other treatment groups. Consequently, the time of degradation by microbes was shorter; hence less ammonia was detected in the rumen fluid.

The proportion of VFA reflects the nature of feeding. In this study, increased concentrate consumption resulted in a decrease in the proportion of acetate, and an increase of propionate. This is in agreement with the findings of other authors (Archimède *et al.*, 1996; Cantalapiedra-Hijar *et al.*, 2009; Dijkstra, 1994). Moreover, propionate is mainly used by the host animal for the biosynthesis of glucose or deposition of body fat (Christopher *et al.*, 2008). This could in turn explain the greater ADG of concentrate-supplemented groups.

3.4.4. Plasma Metabolites

Plasma glutamic-oxaloacetic transaminase (PGOT) activity has long been demonstrated as a reliable index of the onset and regression of nutritional muscular dystrophy (Hull & Scott, 1972). Therefore, alterations in the flux of PGOT can have consequences on muscle tissue growth. Similarly, creatinine levels are associated with growth, muscularity and total body protein mass (Hegarty *et al.*, 2006) while glucose is an index of dietary energy intake. It is logical to infer that the lower and highly variable levels of glucose, PGOT and creatinine before experimental

supplementation were pointers to sub-optimal dietary energy and potentially low body protein mass, growth and muscular tissue development in the goats. However, these were restored to normal levels at the end of the supplementary feeding period, an indication that amelioration was adequately achieved through concentrate supplementation.

Conclusion

Dietary concentrate supplementation of Bach Thao bucks at 1.8%C of body weight on a dry matter basis had the best impact on growth performance, nutrient digestibility and rumen fermentation indices compared with lower levels of concentrate supplementation. There was no further improvement in these indices at higher rates of concentrate supplementation. Therefore, it may well be recommended that local smallholder goat farmers in Vietnam supplement growing animals at 1.8 %C of body weight.

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Chapter 4: Effect of concentrate supplementation on meat yield and quality indices of *Longissimus dorsi* muscle in Bach Thao goats

Q.H. Nguyen^{ab}, P. A. Lane^a, V.H. Nguyen^b, D. Parsons^a, B.X. Nguyen^b, A.E.O. Malau-Aduli^{a*}

^aSchool of Land and Food, Tasmanian Institute of Agriculture, University of Tasmania, Private Bag 54 Hobart, TAS 7001, Australia

^bFaculty of Animal Sciences, Hue University of Agriculture and Forestry, Hue City, Vietnam.

Abstract

The effect of concentrate supplementation on growth, meat yield and quality of Vietnamese Bach Thao goats was assessed. Twenty-five bucks at 7 months of age weighing on the average 20.3 ± 0.9 kg were randomly allocated into five treatment groups in a 9-week feeding trial: Control (*ad libitum* elephant grass), 0.6 %C (control plus 0.6% of concentrates), 1.2 %C (control plus 1.2% of concentrates), 1.8 %C (control plus 1.8% of concentrates), and 2.4 %C (control plus 2.4% of concentrates) as a percentage of liveweight on a dry matter basis. As dietary concentrate levels increased, so did feed intake, average daily gain (ADG), lean meat yield and dressing percentage(DP), but there were no differences in total fat percentage, or L* and b* colour values. The highest ADG of 150g/d and DP of 56% were observed in treatment 1.8 %C. Monounsaturated fatty acids were higher in supplemented groups than in the control group. Therefore, increasing dietary concentrates to 1.8% of liveweight improves growth rate and meat quality of Bach Thao goats.

Keywords: Bach Thao goats; concentrates; meat quality; *Longissimus dorsi*

4.1. Introduction

The demand for goat meat and products has been increasing in both poor and rich countries, due to rising population (Sahlu & Goetsch, 2005). In Vietnam, most goats are kept by smallholders farmers, with typical herd sizes ranging from 5 to 7 head, and mainly located in the mountainous areas with a harsh environment and poor quality feed resources (Mui, 2006). Conventionally, goats in Vietnam graze during the day and are supplemented with forages or concentrates at night. However, the quality of the grazed pasture does not meet the nutrient requirements of goats for high production. In order to meet the nutrient requirements of goats, concentrates are sometimes used as supplementation, particularly in intensive production systems. However, the prices of such concentrates are quite high and account for almost 70% of the total cost of production. Therefore, concentrates made from easily accessible feed resources and supplied at affordable and optimal levels could lead to effective utilization and improve the economic efficiency of goat enterprises.

Besides improving goat productivity, the quality of goat meat needs to be assessed in terms of palatability, appearance, shelf-life and consumer preferences. Meat mono- and poly-unsaturated fatty acids and chemical compositions are linked to human nutrition. It is well documented that goat meat quality is affected by the plane of nutrition, especially concentrate levels in the diet (Haddad, 2005; Lee *et al.*, 2008a; Madruga *et al.*, 2008; Mushi *et al.*, 2010; Ryan *et al.*, 2007; Safari *et al.*, 2009).

There have been a large number of research investigations in different parts of the world into different ratios of forage to concentrates fed to goats. In general, such findings focused on available feeds and genotypes of goats in diverse locations with different livestock production systems. It is difficult to apply these results to livestock production conditions peculiar to Vietnam. Therefore, this research was conducted to test the hypothesis that increased levels of concentrate supplementation to goats will lead to higher productivity and better meat quality. The primary objective of this study was to investigate the effect of concentrate supplementation

levels on growth rate, liveweight, dressing percentage and meat quality attributes of Vietnamese Bach Thao goats.

4.2. Materials and Methods

4.2.1. Animals, feeding management and treatments

The experiment was conducted at Hue University of Agriculture and Forestry Farm in Thua Thien Hue Province (16°00' to 16°48' latitude, 107°48' to 108°12' longitude) in Vietnam.

Twenty-five Bach Thao bucks (initial liveweight = 20.3 ± 0.9 (Mean \pm S.D.), approximately 7 months old) were used for the experiment. On arrival, they were treated for internal and external parasites with Ivermectin (2ml/25kg BW).

Goats were given a three-week adaptation period and randomly assigned to five experimental finishing diets (5 goats per treatment) for six weeks. All experimental animals had *ad libitum* access to the same basal diet of elephant grass. The five treatment groups were: Control (*ad libitum* access to elephant grass), 0.6 %C (control plus 0.6% of concentrates), 1.2 %C (control plus 1.2% of concentrates), 1.8 %C (control plus 1.8% of concentrates), and 2.4 %C (control plus 2.4% of concentrates) as a percentage of liveweight on dry matter basis.

The basal diet (control) of elephant grass was fed at 20% above the previous day's intake. The concentrate was formulated to contain 16% CP and was offered twice daily to the goats before they consumed the elephant grass. The quantity was adjusted weekly in accordance with changes in liveweight. The ingredients in the concentrates and their proportions are depicted in Table 4.1.

Table 4.1 The proportions of ingredients (g/kg DM) and nutrient contents of the mixed concentrate and elephant grass.

Ingredient		Proportion (g/kg DM)
Rice bran		323.4
Maize		333.2
Fishmeal		127.4
Cassava powder		196
Mineral – Vitamin		10
Salt		10
Nutrient composition (%)		
Nutrient (% as DM basis)	Mixed concentrates	Elephant grass
Dry matter	87.2	17.6
Crude protein	15.7	9.2
Organic matter	91.0	89.4
Neutral detergent fibre	30.9	68.7
Acid detergent fibre	5.8	37.5

Bucks were allocated to individual pens (1.5 x 0.75m) with separate feeding and water troughs. Feed residuals were weighed and recorded the following morning before allocating the next day's feed rations. Feed samples were analysed weekly for chemical composition. The liveweight of animals was measured weekly to calculate the weight gain and adjust the concentrate supplementation levels.

4.2.2. Slaughtering procedure and carcass sampling

After 6 weeks of the feeding trial period, the twenty-five goats were slaughtered following 16 hours of fasting and free access to water. The slaughter body weight (SBW) of animals was recorded before slaughter. The goats were slaughtered using standard commercial techniques. The hot carcass weight (HCW) consisted of the body after removing the head, fore feet (at the carpal – metacarpal joint), hind feet (at the tarsal-metatarsal joint), and visceral and other fat

deposits. The HCW included the skinned tail, thymus, lateral portion of the diaphragm, kidneys, perinephric and pelvic fats, and the testes (Colomerocher *et al.*, 1987). The carcass was weighed, and meat colour and pH readings taken. The pH values were measured at 1 hour, 12 hours and 24 hours after slaughter post-mortem at 4°C using portable pH (HI 99163, HANA, USA) and colour indices were measured at 1h after slaughter using (Chroma meters CR 410-Konica Minolta) meters. The values of L*, a*, b* were averages of three measurements of each *Longissimus dorsi* muscle sample. The L* value refers to lightness, a* value to red-green, and b* value to yellow–blue. The weights of blood, internal organs, testes, fat depots and full and empty gastro-intestinal tracts were recorded. Dressing percentage was calculated using the equation: $DP = 100 \times (HCW / SBW)$ where DP is dressing percentage, HCW is hot carcass weight and SBW is slaughter body weight.

The carcass was dissected into two halves through the median plane and weights of both halves were recorded. The tissues of the left half were dissected separately to estimate the total carcass composition regardless of lean meat, bone, and fat. Thereafter, loin muscle (*Longissimus dorsi*) samples were cut out to measure the eye-muscle area at the 12/13th rib position, prior to storage at -20°C.

The *Longissimus dorsi* muscle samples were analysed for intramuscular fat content and fatty acid profiles using the standard GC-MS (Gas Chromatography – Mass Spectrophotometry) method.

4.2.3. Chemical analysis

Nitrogen concentration in the feeds and meat were determined using the Kjeltec 8200 (Foss, Sweden) following the Kjeldahl method. Crude protein concentration was calculated as N x 6.25. Neutral Detergent Fibre (NDF) was analysed using the Fibertec 1020 (Foss, Sweden) as described by Van Soest *et al.* (1991). Dry matter (DM), Ash and Ether extract (EE) were determined according to AOAC (1990).

4.2.4. Statistical analysis

Experimental data were analysed using the Mixed Model Procedure of SAS (2009) where a univariate model fitting treatment as a fixed effect and a random effects was utilized. Duncan's test was used for the separation of significant means at $P < 0.05$ probability level.

4.3. Results

4.3.1. Liveweight changes

With increasing levels of concentrate consumed (from 0 to 495 g/d) grass intake decreased from 429 g/d to 284 g/d (Table 3.2). The total dry matter intake increased ($P<0.05$) from the control treatment (429.1 kg/d) to the 2.4 %C treatment (779.2 g/d). There was also an increase ($P<0.05$) in average daily gain (ADG) when the proportion of concentrates in the diets increased. The 1.8 %C and 2.4 %C treatments resulted in a weight gain of 150 g/d.

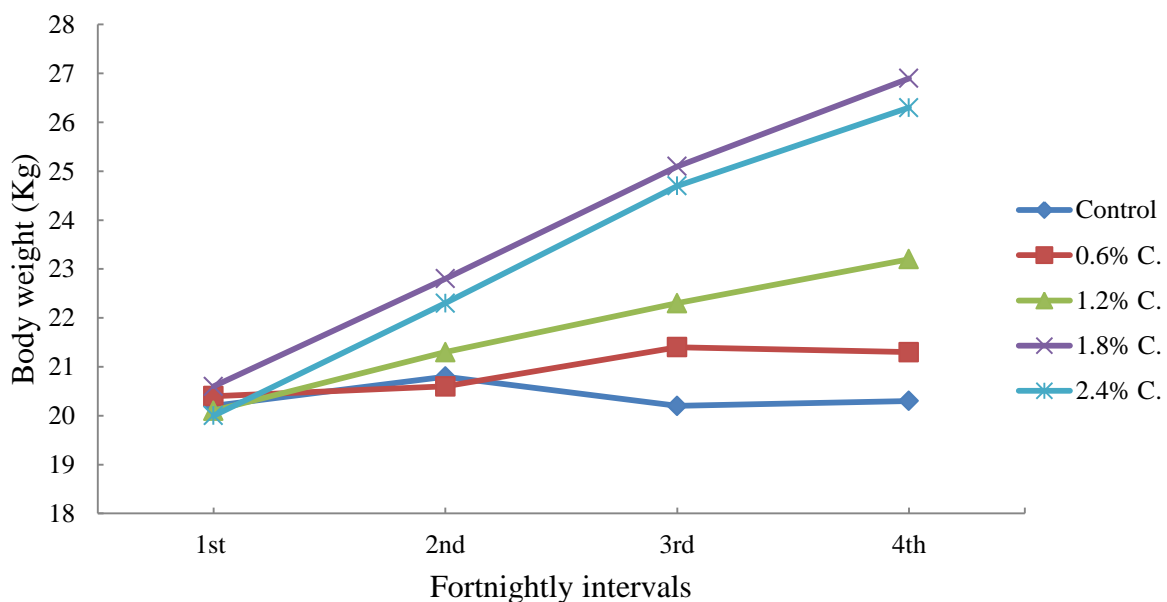


Fig. 4.1 Fortnightly variation in body weight (kg) in goats.

Fig. 4.1 shows the fortnightly changes in liveweight of goats fed different levels of concentrates. The final weight of goats in treatments 1.8 %C and 2.4 %C (~27 kg) was greater than in other treatments, indicating that these goats could reach a commercial finishing weight more quickly than others. Treatments 1.8 %C and 2.4 %C had the same trend throughout the duration of the experiment. The liveweight of goats in the control treatment remained almost unchanged throughout the experimental period.

4.3.2. Carcass tissues and dressing percentage

There was an increase ($p<0.05$) in dressing percentage based on full body weight as the concentrate level in the diets increased (Table 4.2). However, no significant difference was observed between treatments 1.8 %C and 2.4 %C.

Table 4.2 Dressing and meat-bone-fat percentages in the carcass of Bach Thao goat fed varying levels of concentrate (Least Squares Means).

<u>Parameters</u>	Control	0.6 %C	1.2 %C	1.8 %C	2.4 %C
Dressing (%)	48.2±2.6 ^a	50.2±3.8 ^{ab}	52.8±2 ^{bc}	56.2±0.7 ^c	56.7±3.8 ^c
Visceral fat (g)	91±13.4 ^a	340±88.3 ^{ab}	444±138.8 ^b	886±453.4 ^c	834±145.5 ^c
Lean meat (%)	67.5±2.7 ^a	69.4±3.4 ^{ab}	71.3±1.5 ^{ab}	73.6±1.7 ^b	74.4±1.7 ^b
Bone (%)	31.7±2.9 ^a	29.4±3.1 ^{ab}	27.7±1.5 ^{bc}	24.9±2 ^c	24.6±1.6 ^c
Fat (%)	0.8±0.4	1.2±0.4	1±0.7	1.5±0.6	1.1±0.4

^{a-c} Means in the same rows with different superscripts are significantly different ($P<0.05$)

The lean meat percentage ranged from 67.5 to 74.4 % (Table 4.2) and the treatment 1.2 %C, 1.8 %C and 2.4 %C were significantly ($P<0.05$) higher than the control treatment. Conversely, the bone proportion decreased ($p<0.05$) with increasing concentrate levels, with the lowest percentage found in treatments 1.8 %C and 2.4 %C (approximately 25%). However, there was no significant difference in fat content between concentrate treatments.

The levels of visceral fat in treatments 1.8 %C and 2.4 %C (886 g and 834 g, respectively) were not significantly ($P>0.05$) different from each other, but were greater ($P<0.05$) than for the other treatments. The lowest visceral fat weight of 91 g was observed in the control treatment.

4.3.3. PH and colour indices of *Longissimus dorsi*

There was a significant difference in the a^* value between treatments, goats in the control treatment had a higher value than the concentrate-supplemented groups; however L^* and b^* values were not different ($P>0.05$) (Table 4.3).

The pH value observed in the control diet (6.6) was significantly higher ($p<0.05$) than in treatments 1.2 %C and 1.8 %C. The pH values of concentrate-supplemented groups were not different from each other, and ranged from 6.1 to 6.3 (Table 4.3).

Table 4.3 Colour and pH indices of *Longissimus dorsi* muscle of Bach Thao goats.

	Control	0.6%C	1.2%C	1.8%C	2.4%C
L^* value	39.6±1.8	38.9±1.1	39.6±4.4	39.1±2	38.9±3
a^* value	21.9±1.5 ^a	19.9±0.5 ^b	20.2±0.5 ^b	19.5±0.7 ^b	19.4±1.2 ^b
b^* value	4.4 ±0.9	3.5±0.4	3.8±1.1	3.5±0.6	3.7±1.7
pH value	6.6±0.3 ^a	6.3±0.2 ^{ab}	6.1±0.3 ^b	6.2±0.2 ^b	6.3±0.3 ^{ab}

^{a-c} Means within the same row with different superscripts are significantly different ($P<0.05$)

Fig 4.2 shows the decrease in pH of the *Longissimus dorsi* muscle from 1 hour to 24 hours after slaughter. There were decreases in all five treatments, and in the four concentrate - supplemented groups, pH ranged from 5.8 to 6.0 after 24h post mortem.

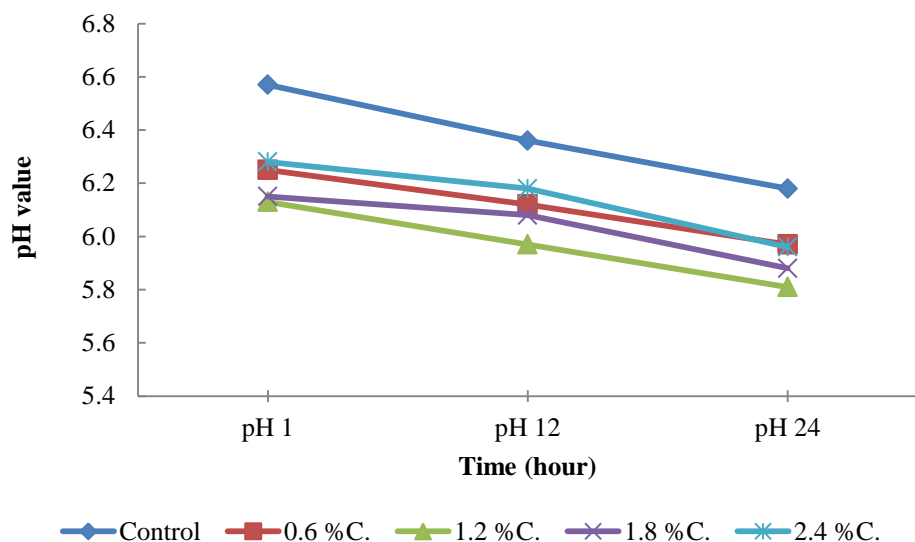


Fig. 4.2 Change in pH of the *Longissimus dorsi* muscle after 24h post mortem of goats fed different levels of concentrate.

4.3.4. Chemical composition of the *Longissimus dorsi* muscle

The DM content of the *L. dorsi* muscle from the control diet was significantly ($P<0.05$) less than in other treatments, except for treatment 0.6 %C, while other indices were not different ($P>0.05$) between treatments (Table 4.4). Although there was no significant difference, the EE tended to be higher in concentrate treatments (6.2 to 9.2%) than the control treatment (4.8%). The CP and ash of *L. dorsi* muscles were no significant difference between treatments (Table 4.4).

Table 4.4 Chemical composition of the *Longissimus dorsi* muscle of Bach Thao goats (%).

Items	Control	0.6 %C	1.2 %C	1.8 %C	2.4 %C
Dry matter	19.9±0.8 ^a	21.2±0.7 ^{ab}	22.4±1.5 ^b	22.2±0.4 ^b	22.5±1.2 ^b
Crude protein	91.8±1.2	87.1±5.2	87.4±3.3	89.6±1.3	87.3±2.8
Ether extract	4.8±1.2	9.2±5.3	8.8±2.7	6.2±1.2	8.8±2.9
Ash	5.1±0.2	4.8±0.3	4.8±0.3	4.8±0.1	4.8±0.3

^{a-c} Means within the same row with different superscripts are significantly different ($P<0.05$)

4.3.5. Fatty acid composition of *Longissimus dorsi* muscle

The fatty acid composition of the *L. dorsi* is presented in the Table 4.5. The three main fatty acids (FA) in the muscle were palmitic (C16:0; 17.65 to 20.33%), stearic (C18:0; 14.3 to 20.14%), and oleic (C18:1; 29.84 to 46.86%) acids. The treatment diets affected the percentages of total unsaturated (USFA), desirable (DFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids ($p < 0.05$), but did not have an impact on total saturated (SFA) fatty acids ($P > 0.05$). The percentages of USFA, DFA, and MUFA in the *L. dorsi* of supplemented groups were higher than in the control treatment. Conversely, the control diet had the highest PUFA proportion which was significantly higher than all other treatments.

Table 4.5 Fatty acid composition of the *Longissimus dorsi* muscle of Bach Thao goats (%).

Fatty acid	Control	0.6 %C	1.2 %C	1.8 %C	2.4 %C	Significance
C10:0	0.2	0.1	0.1	0.1	0.1	NS
C12:0	0.3	0.1	0.1	0.1	0.1	NS
C14:0	1.6	1.1	1.4	1.1	1.3	NS
C16:0	17.7	18.4	20.3	19.8	19.9	NS
C16:1	1.5	2.1	1.6	1.7	1.1	NS
C18:0	17.4 ^{ab}	16.6 ^{ab}	20.1 ^a	14.4 ^b	14.3 ^b	*
C18:1	29.8 ^a	38.8 ^b	41.5 ^{bc}	44.7 ^{cd}	46.9 ^d	*
C18:2	6.4 ^a	5.1 ^{ab}	3.8 ^b	5.7 ^{ab}	5.6 ^{ab}	NS
C18:3	1.2 ^a	0.8 ^b	0.5 ^c	0.5 ^c	0.4 ^c	*
C20:0	0.5 ^a	0.5 ^a	0.5 ^a	0.8 ^b	0.9 ^b	*
C20:4	6.9 ^a	4.1 ^b	2.1 ^c	2.3 ^{bc}	2.2 ^c	*
SFA	36.7	36.4	42.5	36.2	36.3	NS
USFA	45.7 ^a	50.6 ^b	48.9 ^{ab}	54.9 ^c	56 ^c	*
DFA	63.1 ^a	67.2 ^b	69.1 ^b	69.3 ^b	70.3 ^b	*
MUFA	31.3 ^a	40.9 ^b	43.1 ^{bc}	46.4 ^{cd}	47.9 ^d	*
PUFA	14.4 ^a	9.7 ^b	5.8 ^b	8.5 ^b	8.1 ^b	*

NS= non-significant, * = significant, SFA= Saturated Fatty acids, USFA= Unsaturated Fatty Acids, DFA= Desirable Fatty Acid (sum of C18:0 and USFA), MUFA=Monounsaturated Fatty Acids, PUFA=Poly Unsaturated Fatty Acids.

^{a-c} Means in the same row with different superscripts are significantly different (P<0.05)

4.4. Discussion

4.4.1. Feed intake and average daily gain

The observation in our study where total feed intake increased linearly with the level of concentrate offered is in agreement with Haddad (2005) who reported a similar trend when goats were fed varying proportions of concentrates ranging from 40 to 85% of the diets. Goats in the present study were offered concentrates rich in energy and protein before being fed grass, therefore, there was a reduction in grass intake, consistent with observations by Safari, *et al.*, (2009) in which hay intake reduced with increased concentrate intake. Concentrates have a faster digestion, hence a shorter rumen retention time in ruminants. Thus, goats fed concentrates could consume comparatively more concentrates than grass only, increasing the total intake and consequently the ADG. Although the total DM intake of goats in treatment 2.4 %C was greater than in treatment 1.8 %C, both treatments had the same average daily gain (ADG)(150 g/d), indicating that there is a limit to the benefit of substituting grass with concentrate. It would be more economical for Bach Thao goat farmers to supplement at 1.8 %C and yet achieve the same growth levels as 2.4 %C.

The lowest ADG (2.4g/d) was obtained in goats in the unsupplemented control treatment, fed elephant grass only. This was not entirely surprising because with a CP of 9%, the elephant grass was only supplying just enough protein for maintenance. Other researchers have reported increases in ADG of goats fed varying ratios of concentrate: forage (Corrigan *et al.*, 2008; Haddad, 2005).

4.4.2. Meat to bone ratio, visceral fat and dressing percentage

There was a substitution effect between bone and meat proportions in the carcass as increasing concentrate level in the diets produced more meat. The skeleton is well developed early in life, therefore it was unsurprising that the total bone weights of the animals in our experiment were not different. The fat in the carcass was not different between treatment groups, as typically the first priority of fat accumulation is visceral fat (Webb *et al.*, 2005). Visceral fat increased

significantly with increased concentrate supplementation, in agreement with other studies (Liméa *et al.*, 2009; Safari *et al.*, 2009).

Dressing percentage based on full body weight is an important commercial index for assessing the edible parts of slaughtered animals. Although the dressing percentage in this study ranged from 48 to 56% and was higher than the range of 42-50% reported by Mushi *et al.*, (2009) and Safari *et al.*, (2009). The result might be due to variation in breed type, age at slaughter, or even slaughter procedure. However, the trend of increasing dressing percentage with increase in concentrate levels in this study is in agreement with previous reports by Mushi, *et al.*, (2009).

4.4.3. Colour and pH of the *Longissimus dorsi* muscle

Goats fed grass had a greater a* value than concentrate-supplemented goats in other treatment groups. This observation is in contrast to the report of Ryan *et al.*, (2007) that compared pasture-fed and concentrate-supplemented crossbred Boer goats and observed higher values of a* and b* in goats fed concentrate than those fed grass only. The b* value implies the yellowness of meat colour, and varies widely in different experiments reported in the literature. The b* value range in our current study (3.5-4.4) was much lower than the range reported by Ryan *et al.*, (2007) (10.9-12.6), but consistent with the findings of Kadim *et al.*, (2003) in Omani goats. This variation could be basal feed or breed-dependent. The L* (lightness) and a* (redness) value ranges in our study were 38 to 39, and 19 to 21, respectively, and correspond with the same range reported by Ryan *et al.*, (2007).

The pH value of unsupplemented goats was higher than the value in concentrate-supplemented treatment groups. A possible explanation for this observation could be due to lower glycogen concentration in the meat because of the lower energy density of the diet.

4.4.4. Fatty acid profiles of the *Longissimus dorsi* muscle

The proportion of DFA detected in the present study ranged from 63 to 70%, which falls within the normal range expected of goat meat (Banskalieva *et al.*, 2000). The observed increase in the proportion of DFA as the level of concentrate increased in the diets is in agreement with the findings of Mushi *et al.*, (2009). In the present study, the control diet had a higher proportion of octadecatrienoicacid (C18:3) than the concentrate-supplemented treatments, in line with the findings of Lee *et al.*, (2008b). This could be attributable to a greater proportion of PUFAs, characteristic of grass diets. Our results are also consistent with the review by Lee & Kannan (2012), in which goats fed pasture only had a similar proportion of SFA, lower MUFA and greater PUFA than those fed concentrate supplements.

Conclusion

Concentrate improved goat liveweight gains leading to a quicker attainment of commercial slaughter weight. Furthermore, goats fed concentrate produced higher lean meat yields than unsupplemented goats. An increase in the proportion of concentrate in the diets resulted in greater levels of DFA in the *Longissimus dorsi*, which is believed to be favourable to consumer health. In general, supplementing goats with concentrate up to 1.8% of their body weight improved both meat quantity and quality.

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Chapter 5: Small Ruminant Nutrition System Model: Comparative evaluation of prediction accuracy between observed and predicted data

5.1 Introduction

Nutrition models have been developed for many livestock species. The small ruminant nutrition system (SRNS) was built based on the structure of the Cornell Net Carbon and Protein System for sheep (Cannas *et al.*, 2007). The purpose of the model is to help farmers, researchers and extension personnel develop improved feeding management strategies. The SRNS model can assist in assessing a range of different physiological and management aspects, from rumen fermentation to economic policies designed to support livestock production (Tedeschi *et al.*, 2011).

The dominant feeding system for goats in Vietnam is grazing on common land with native grass in the day time, supplementing with crop by-products, cut-and-carry cultivated or native grass and sometimes the use of concentrates during the finishing period. However, the area of common land is reducing quickly in comparison with increasing numbers of goats. The system of semi-intensive cattle production, supplying feeds to confined animals (Nguyen *et al.*, 2008), could potentially be economically applied to goats. In the semi-intensive system, understanding the nutrition, production, and feeding management is critical.

Therefore, a functioning nutrition model that can accurately predict results of feed intake and goat performance can play a crucial role in the development of improved feeding strategies. This could potentially help not only individual farms, but also provide support for local policy makers.

The objective of this chapter was to evaluate the ability of SRNS model to predict the dry matter intake (DMI), average daily gain (ADG), nutrient digestibility and characteristics of faecal output of Vietnamese Bach Thao goats.

5.2 Materials and methods

5.2.1. Database description

The database used in this chapter was based on the experiment previously reported in Chapter 3. A summary of the experimental data used for parameterisation is given in Table 5.1.

Table 5.1 Summary of experimental details used to parameterise the SRNS model.

Parameters	Experiment
Breed	Bach Thao
N	25
Initial experimental body weight (kg) (Mean \pm SD)	20.3 \pm 0.8
Initial model parameter body weight (kg) (Mean \pm SD)	22.0 \pm 1.7
Initial age (months)	7
Number of treatments	5
Variable treatments	Concentrate levels

Feed samples were analysed by a commercial laboratory (Cumberland Valley Analytical Services, Hagerstown, Maryland, USA) for dry matter (DM; AOAC, 2000; method 930.15), ash (AOAC, 2000; method 942.05), crude protein (CP; AOAC, 2000; method 990.03), lignin determined by solubilisation of cellulose with sulphuric acid, neutral detergent fibre [NDF; (Van Soest *et al.*, 1991)], acid-detergent insoluble fibre protein [ADIP; (Licitra *et al.*, 1996)], and neutral-detergent insoluble protein [NDIP; (Licitra *et al.*, 1996)], and ether extract (EE; AOAC, 2006; method 2003.05). The chemical compositions of the experimental feeds are detailed in Table 5.2.

Table 5.2 Feed quality values used to parameterise the small ruminant nutrition system model.

Component	Unit	Napier grass offered	Napier grass residue	Ricebran	Cassava powder	Corn powder	Fishmeal powder
Dry matter	% DM	17.6	21.5	87.3	87.7	88.6	82.7
Crude protein	% DM	9.0	7.1	15.1	2.4	9.4	63.8
Soluble protein	% CP	23.1	23.1	20.1	17.1	6.2	38.4
Acid detergent fibre	% DM	36.9	46.0	11.0	3.7	3.2	1.1
Neutral detergent fibre	% DM	60.5	70.0	19.9	5.1	10.4	3.7
ADF insoluble protein	% DM	1.0	1.1	1.4	0.4	0.6	0.7
NDF insoluble protein	% DM	2.2	2.3	1.5	0.5	0.8	2.5
Lignin	% DM	4.0	12.5	3.3	1.3	1.1	0.6
Sugar	% DM	12.6	11.4	4.1	3.7	0.6	3.2
Starch	% DM	2.0	2.5	39.1	85.1	75.4	0.2
Crude fat	% DM	1.6	1.3	14.6	0.5	1.8	2.7
Ash	% DM	16.5	9.6	8.7	3.8	3.3	28.8
Calcium	% DM	0.36	0.36	0.07	0.09	0.02	6.96
Phosphorus	% DM	0.33	0.29	1.73	0.10	0.34	3.15

The original results of chemical composition did not add up to 100% of DM, due to errors in the analysis processes. To adjust for this, for each ingredient, the error (i.e. the difference between 100 and the sum of all ingredients) was allocated to each chemical component in proportion to the contribution to dry matter before adjustment. This approach makes no assumptions about the likelihood of the analysis of each chemical component introducing error. The method of analysis also does not take into account potential DM contributions from soluble fibre or organic acids.

The SRNS version 1.9.4468 (<http://nutritionmodels.tamu.edu/srns.html>) was used to predict animal intake and performance.

Additional input data needed for simulation are detailed in Table 5.3. The model was calibrated and run separately for each animal from the experiment. The initial weights used in the model

were the average weights (final minus initial, divided by 2) of each animal during the 6 week experimental period. Hence, the initial weight was specified differently for each simulation.

Table 5.3 Input variables used to evaluate the small ruminant nutrition system (SRNS) model.

SRNS input	Experiment values
Animal type	Male kid
Indigenous (Y/N)	Yes
Full body weight (kg)	Inputted for each individual, Range (19 to 25.4)
Standard reference weight at body condition score 2.5 (kg)	50
Current temperature (°C)	25
Previous temperature (°C)	20
Wind speed (kph)	0
Rainfall (mm/d)	0
Horizontal distance km/d)	0.1
Vertical distance (km/d)	0

5.2.2. Model evaluation

The Model Evaluation System (MES; Tedeschi, 2006; <http://nutritionmodels.tamu.edu/mes.html>) was used to test the level of precision and accuracy of the model predictions. This is a crucial step of the modelling process, as discussed by Tedeschi (2004). There are several quantitative statistics used to test the adequacy of the model. They included the root mean squared error (RMSE), coefficient of determination (r^2) of the linear regression between observed and model-predicted values, the slope (b), the intercept (a) and their standard deviation and probability of $b = 1$ and $a = 0$.

5.3 Results

Table 5.4 contains the descriptive and adequacy statistics comparing observed and model-predicted DMI (Dry matter intake), ADG (Average daily gain), digestibility of nutrition and faecal output characteristics.

Table 5.4 Coefficient of determination (r^2), root mean square error (RMSE), slope (b), and y-intercept (a) for regression of observed and model-predicted outputs.

Parameter	r ²	RMS E	Slope			Intercept		
			b	SD _b	Prob. b=1	a	SD _b	Prob. a=0
<i>Growing period</i>								
DMI	0.77	0.07	1.26	0.14	0.078	0.05	0.06	0.46
ADG	0.75	34.8	0.93	0.11	0.523	39.4	8.45	0.0001
<i>Digestibility period</i>								
DMI	0.38	0.11	0.64	0.17	0.042	0.21	0.09	0.029
DMD	0.82	4.15	1.22	0.12	0.078	-7.65	7.97	0.35
DOM	0.67	3.99	0.72	0.10	0.012	23.5	7.30	0.004
DCP	0.39	3.93	0.41	0.11	<0.0001	45.1	7.2	<0.0001
<i>Faecal output</i>								
DM	0.66	17.02	0.55	0.08	<0.0001	55.8	15.25	0.001
OM	0.63	14.80	0.54	0.09	<0.0001	47.8	12.36	0.0008
CP	0.66	3.14	0.82	0.12	0.152	1.75	2.76	0.53

5.3.1 Growing period

The linear regressions for observed and model-predicted DMI (kg/d) and ADG (g/d) for the 6 weeks of the feeding trial are shown in Figures 5.1 and 5.2.

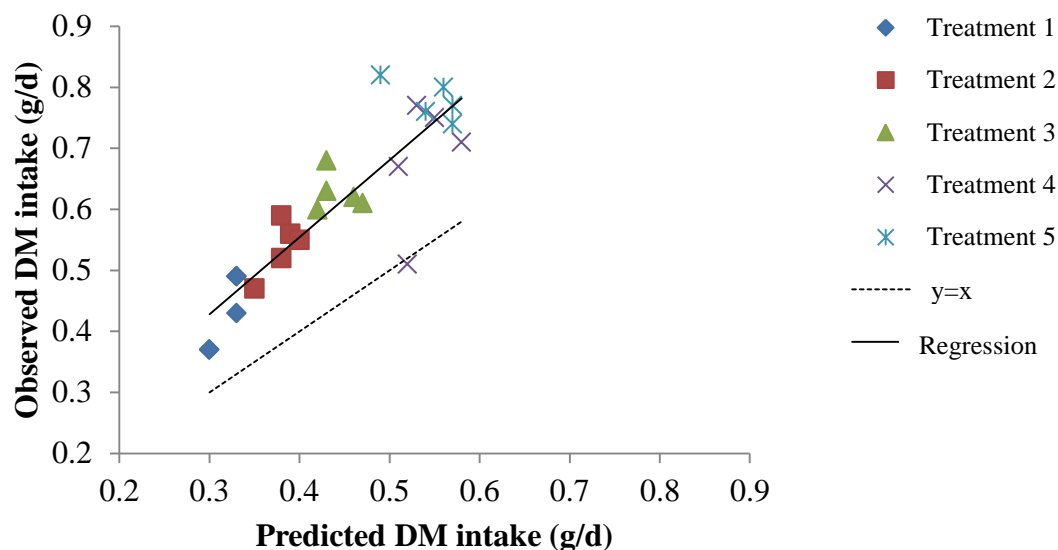


Figure 5.1 Relationship between observed and model-predicted dry matter intake (DMI) using the Small Ruminant Nutrition System.

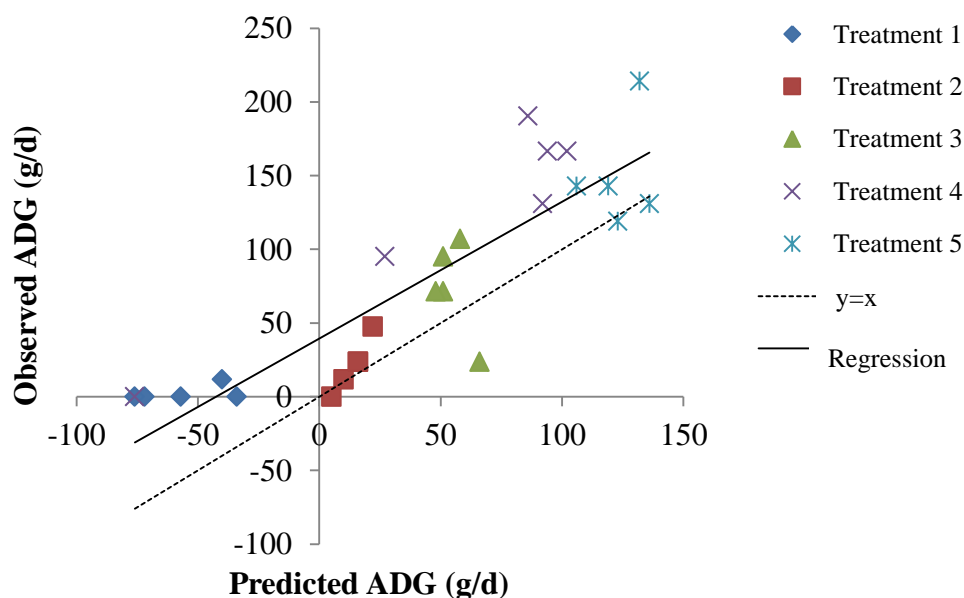


Figure 5.2 Relationship between observed and model-predicted average daily gain (ADG) using the Small Ruminant Nutrition System.

The model under-predicted DMI of animals in all treatments (Figure 5.1). The extent of under-prediction ranged from 0.11 to 0.23 kg/d. Model precision was good, with a coefficient of determination (r^2) of 0.77 and RMSE of 0.07 g/d (Table 5.4). There was no evidence ($P<0.05$) to

suggest that the slope was different from 1 or that the y-intercept was different from 0 (Table 5.4). Similarly, ADG was under-predicted (Figure 5.2), but with good precision ($r^2 = 0.75$) and RMSE (34.8 g/d). There also was no evidence ($P < 0.05$) to reject the hypothesis that b equals 1, however there was evidence that the y-intercept was different from zero ($a = 39.4$). On average, the model under-predicted ADG by 36 g/d and the error is roughly similar for different magnitudes of ADG.

5.3.2 Digestibility period

5.3.2.1 Drymatter intake

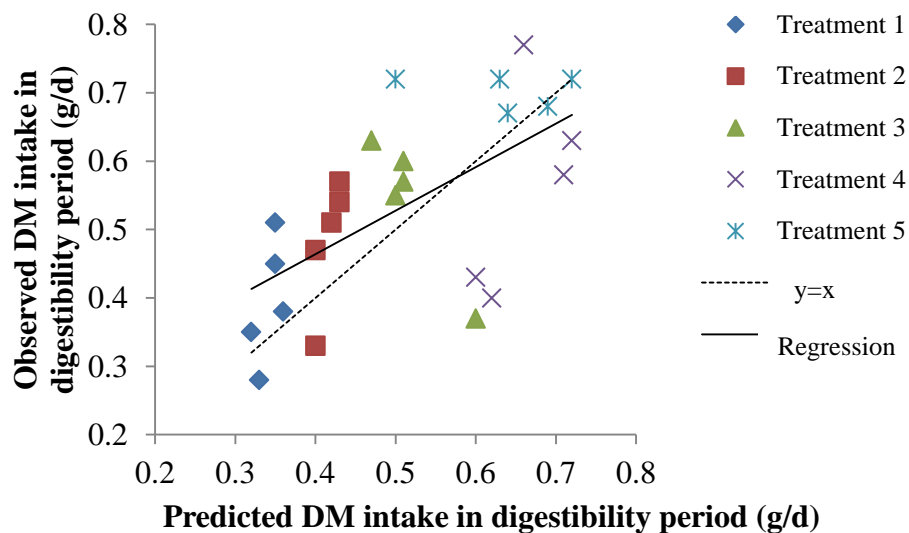


Figure 5.3 Relationship between observed and model-predicted dry matter intake (DMI) for the digestibility period, using the Small Ruminant Nutrition System.

There was a significant slope effect as there was no evidence ($P < 0.05$) to suggest that slope was equal to 1 and the y intercept was equal to 0. Thus, the model under-predicted DMI for lower levels of feed intake and over-predicted for greater levels. The precision value was quite low ($r^2 = 0.38$) compared to DMI during the growing period ($r^2 = 0.77$). The RMSE (0.11) was also greater than that of DMI during the growing period (RMSE = 0.07).

5.3.2.2. Nutrient digestibility

The linear regressions between observed and model-predicted DM, OM, and CP digestibility are depicted in Figures 5.4, 5.5, and 5.6.

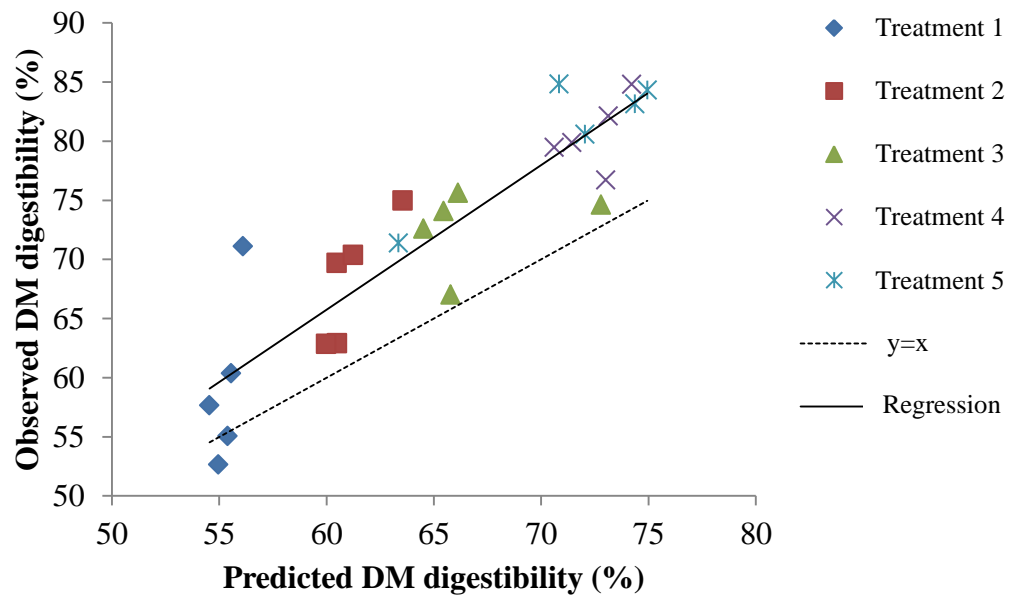


Figure 5.4 Relationship between observed and model-predicted digestibility of dry matter (DDM) using the Small Ruminant Nutrition System.

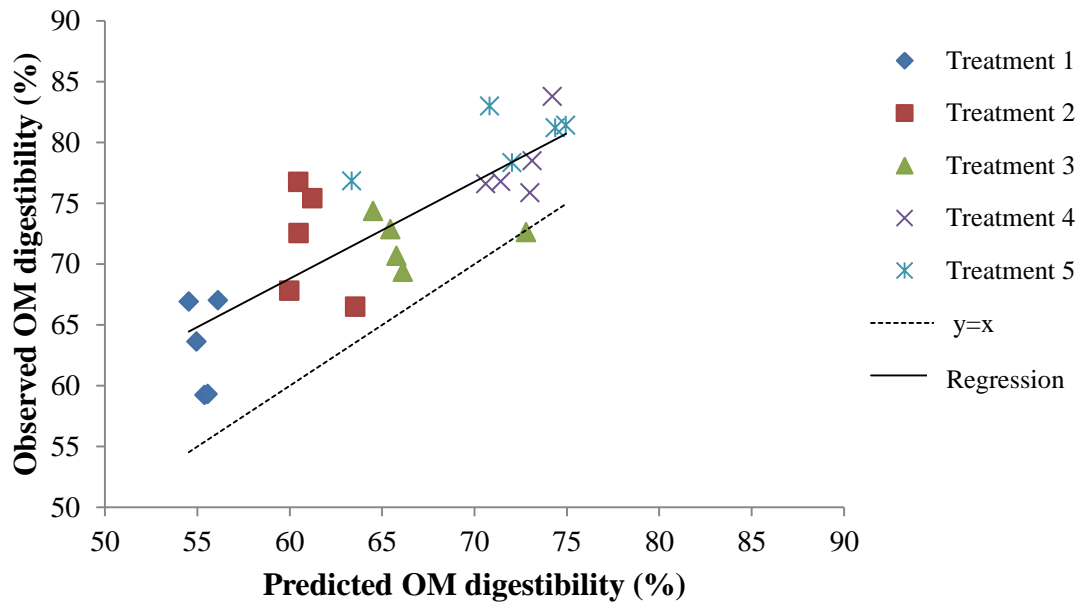


Figure 5.5 Relationship between observed and model-predicted digestibility of organic matter (DOM) using the Small Ruminant Nutrition System.

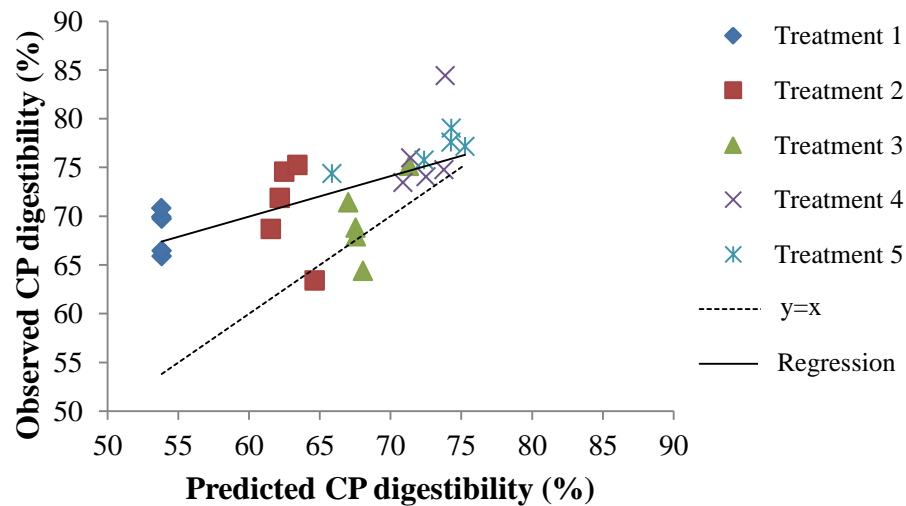


Figure 5.6 Relationship between observed and model-predicted digestibility of crude protein (DCP) using the Small Ruminant Nutrition System.

Figures 5.4, 5.5 and 5.6 show a general under-prediction of nutrient digestibility results. The precision value of digestibility of DM was the highest ($r^2 = 0.82$) compared to values for digestibility of OM and CP ($r^2 = 0.67$ and 0.39 , respectively) (Table 5.4). There was no evidence ($P < 0.05$) to show that the slope and y-intercept of the linear regressions for digestibility of OM

were different from 1 and 0, respectively. The slope of the CP digestibility regression equation was significantly less than 1, while the y-intercept was significantly different to 0; thus the model under-predicted for lower levels of digestibility and over-predicted for higher levels (Figure 5.6).

5.3.3 Faecal output results

The linear regressions between observed and model-predicted chemical composition of faecal outputs (DM, OM and CP) are presented in Figures 5.7, 5.8, and 5.9.

In general, the model predicted lower levels of faecal characteristics (DM, OM and CP) than was observed. The values of precision for DM, OM and CP output were $r^2 = 0.66$, 0.63 , and 0.66 , respectively (Table 5.4). There was no evidence ($P < 0.05$) to suggest that the slope and intercept of the linear regression equation between observed and predicted of CP output were different from 1 and 0 respectively, while slopes and intercepts for DM and OM of faecal output were significantly different from 1 and 0.

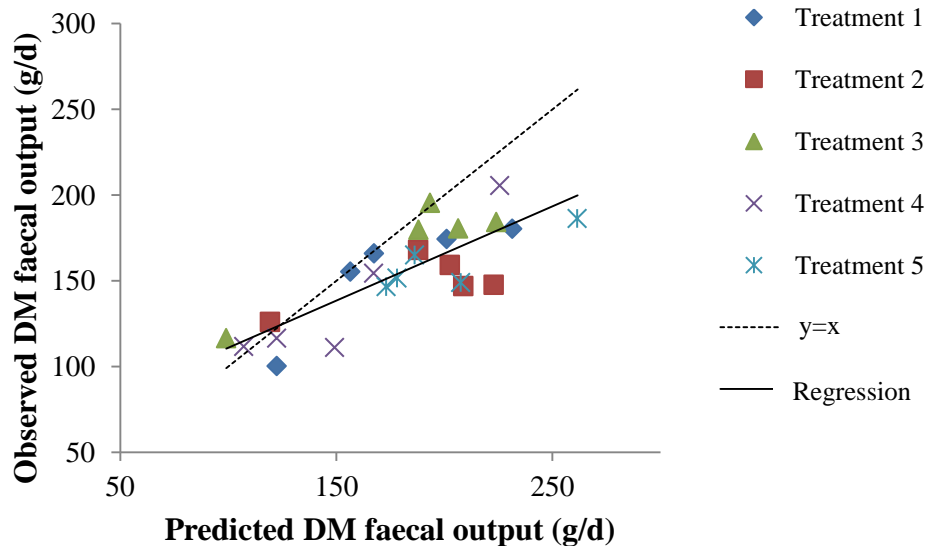


Figure 5.7 Relationship between observed and model-predicted dry matter faecal output using the Small Ruminant Nutrition System.

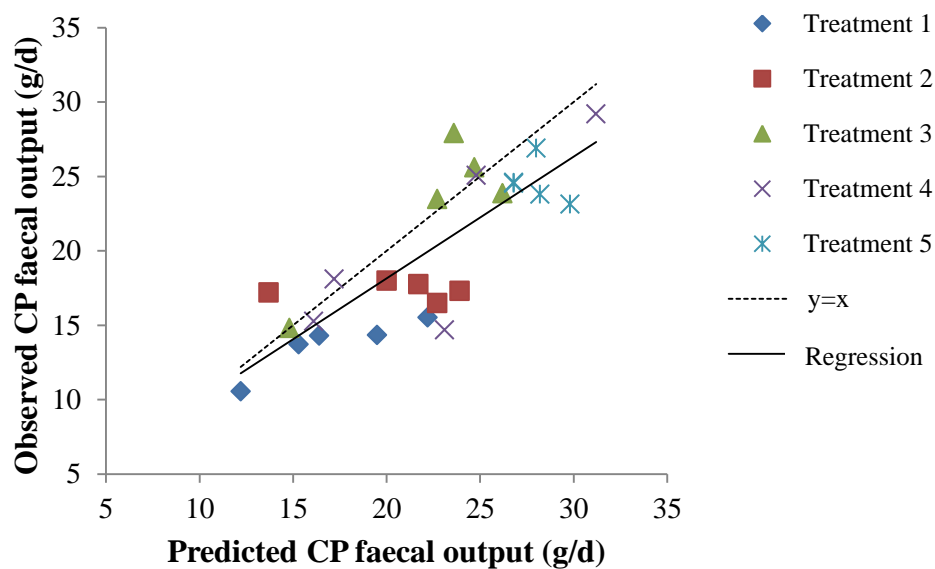


Figure 5.8 Relationship between observed and model-predicted crude protein faecal output using the Small Ruminant Nutrition System.

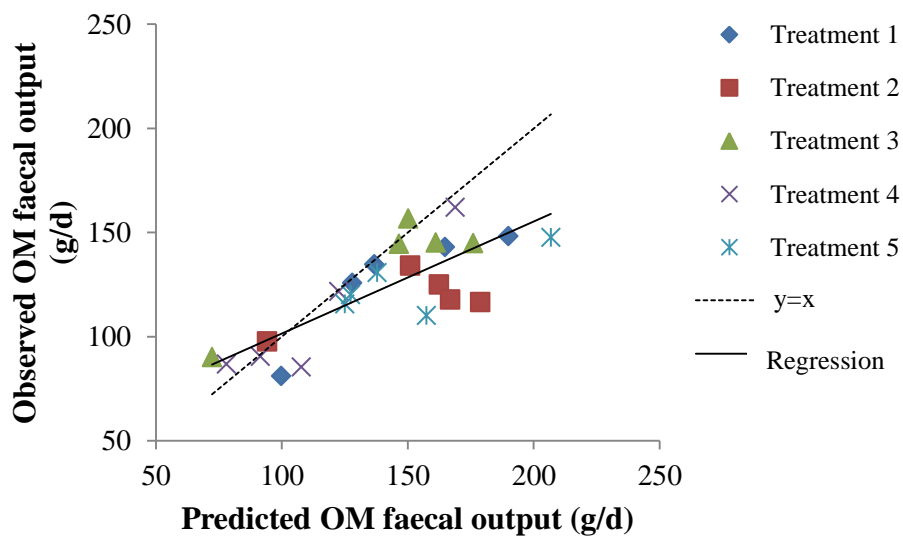


Figure 5.9 Relationship between observed and model-predicted organic matter faecal output using the Small Ruminant Nutrition System.

5.4 Discussion

The SRNS model underestimated DMI and ADG in the growing period compared to observed values. These results are in agreement with findings by Avila-Stagnoa *et al.* (2013) on growing Canadian Arcott lambs. In this study, the magnitude of underestimation of DMI and ADG were 0.025 ± 0.03 kg/d and 91 ± 18 g/d, respectively. The magnitude of under-prediction of DMI was lower in their study than in the present result; however, the ADG value herein was greater.

The level of precision (r^2) and RMSE in the present study demonstrated the highly significant relationship between observed and predicted values. Cannas *et al.* (2007) reported similar statistics ($r^2 = 0.85$, RMSE = 32.5 g/d) for ADG prediction of growing kids using SRNS based on literature data. Feed intake depends on breed and feeding, hence it directly affects animal performance (ADG). In this experiment and analysis, the Vietnamese Bach Thao goat, a tropical breed, was used, which could be different in some physiological and bio-chemical characteristics compared to temperate breeds upon which the model is based. Hence, there may be differences in high temperature stress and the ability to utilize low quality forages (e.g. elephant grass). In addition, the experimental goats were offered concentrates before access to elephant grass, potentially leading to a high passage rate of nutrients from concentrates and less retention time in the rumen, thus making the animals to consume more feed. This could be a major factor in explaining the under-estimation of DMI and ADG by the model and could explain the underestimation of nutrient digestibility.

A difficulty faced when calibrating the model was the specification of the chemical characteristics of the feed. The chemical composition had errors in the analysis processes and the passage rates (kd) of ingredients used in this experiment were unknown. Thus, the chemical components were adjusted to add up to 100% of DM and assumed that the kd parameters were the same as similar feeds contained in the feed library of the model. These assumptions are not ideal and could have also led to introduced error.

Conclusions

The study indicated that SRNS can predict the DMI and ADG of Vietnamese Bach Thao goats with satisfactory results for different ratios of forage and concentrate, when chemical compositions of the feeds are known. The digestibility of DM and OM can also be predicted well by the model. Results for faecal output could be used to assess the quantity and quality of manure outputs from goat production systems, which may have implications for use of manure in crop production, and the potential environmental implications of manure production. The regression equations developed in this study could be used to adjust SRNS outputs to predict the results of production systems.

Further comprehensive evaluation with more data from other studies using Vietnamese breeds and feed sources are recommended.

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Chapter 6: General summary and conclusion

6.1. Feed intake and average daily gain

Total dry matter intake and ADG were measured to assess the response of goats to varying levels of concentrates. Increased levels of concentrate supplementation resulted in increased total dry matter intake. There was a replacement or substitution effect between grass and concentrates consumed in which grass intake reduced when the level of concentrate supplementation increased. Even though goats in treatment 2.4 %C consumed significantly greater dry matter than all the other treatments, the ADG in both treatments 1.8 %C and 2.4 %C were the same result (150 g/d). This suggests that there is a limitation to the substitution effect between grass and concentrates. Thus, dietary concentrate supplementation at 1.8 %C level is recommended as the optimal level for the best ADG response in Bach Thao goats because it is more affordable/cheaper than supplementing at 2.4 %C to attain daily growth of 150g/day.

6.2. Nutrient digestibility and rumen fluid characteristics

The digestibilities of DM, OM, CP and NDF for varying levels of concentrate supplementation presented in Chapter 3 demonstrated that increased concentrate levels led to increases in digestibility, and hence nutrient utilisations of DM, OM and CP.

In terms of rumen volatile fatty acids, the present experiment recorded an increase in propionic acid when the concentrate level consumed increased, while that of acetic acid decreased. This is consistent with other authors (Archimède et al. 1996; Cantalapiedra-Hijar et al. 2009). Dijkstra (1994) also concluded that fermentation of structural carbohydrates results in high amounts of acetic acid and low amounts of propionic acid compared to fermentation of starch.

6.3. Meat quantity and quality

The meat quantity and quality responses of goats to concentrate supplementation were presented in Chapter 4. It was apparent that increased concentrate supplementation resulted in a significant increase in dressing percentage, lean meat proportion in the carcass and visceral fat weight. Meanwhile, the proportion of bone in the carcass decreased with increasing level of concentrates, while that of fat was not different between treatments. This implies that viscera are the first priority depot for fat accumulation; hence, less fat was accumulated in the carcass than the viscera. An increase in concentrate level did not affect the proportions of total saturated fatty acids or chemical composition of the *Longissimus dorsi* muscle, however it significantly increased the percentage of desirable total unsaturated fatty acids.

6.4. General conclusions

It was evident that concentrate supplementation improved goat performance, resulting in greater feed intake, ADG and nutrient digestibility than in unsupplemented goats. Furthermore, concentrate supplementation resulted in a higher dressing percentage and greater lean meat proportion than in unsupplemented goats. The level of desirable total unsaturated fatty acids also increased as the dietary concentrate level increased. In general, dietary concentrate supplementation of Bach Thao bucks at 1.8 %C of body weight on dry matter basis elicited the best results. This thesis has provided empirical data to answer the research questions, aims and objectives, and the hypothesis of this study can be accepted.

Appendix

Appendix 5.1 The initial weights of goats used as inputs in the model.

Animal	1	2	3	4	5	6	7	8	9	10	11	12	13
Weight (kg)	21.9	21.5	23.6	19	23.3	22.3	18.9	21.1	20.6	20.8	21.6	20.9	22
Animal	14	15	16	17	18	19	20	21	22	23	24	25	
Weight (kg)	19.3	22.9	21.6	23.6	21.9	22.6	21.9	21.3	25.4	24.8	24.3	24.3	

Appendix 5.2 Dressing percentage ($M \pm S.D.$) of goats fed different levels of concentrates.

